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CLERK, U.S. DISTRICT COURT
SOUTHERN DISTRICT OF CALIFORNIA
BY: [signature] DEPUTY

UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF CALIFORNIA

PULSE~LINK INCORPORATED, Plaintiff, v. TZERO TECHNOLOGIES INCORPORATED, Defendant.	Case No.: '07 CV 2156 BTM (WMc) **COMPLAINT FOR PATENT INFRINGEMENT AND INJUNCTIVE RELIEF** **(DEMAND FOR JURY TRIAL)**

ORIGINAL

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Plaintiff PULSE~LINK Incorporated ("PULSE~LINK" or "Plaintiff") alleges for its complaint as follows:

NATURE OF THE ACTION

1. This is an action for patent infringement which is generally directed to Ultra-Wideband communication technology that enables, among other things, the high-speed data distribution of high definition TV and multimedia content over both wired and wireless connections. For example, using PULSE~LINK's patented technology, existing coaxial cabling can be used. Flat panel TVs and other devices can be placed around a home and using Ultra-Wideband signals can be operated without tearing open walls to run new cabling. Video recorded in one room can be seamlessly accessed from another either wirelessly or over the coaxial cable.

2. By making, using, offering for sale, and/or selling infringing products that are intended to communicate using Ultra-Wideband communication technology, TZero is depriving PULSE~LINK of its exclusive right to use and profit from its inventions.

THE PARTIES

3. Plaintiff PULSE~LINK is a corporation organized and existing under the laws of the state of Delaware, with its principal place of business at 1969 Kellogg Avenue, Carlsbad, California 92008.

4. Defendant TZero Technologies Incorporated ("TZero") is a corporation organized and existing under the laws of the state of Delaware, with its principal place of business at 455 West Maude Ave. Ste 100 Sunnyvale, California 94085.

5. TZero is doing business in California and in this district.

JURISDICTION AND VENUE

6. This is an action for patent infringement. The patent claims arise under the patent laws of the United States, Title 35 U.S.C. §§ 1, *et seq.* This Court has subject matter jurisdiction over these claims pursuant to 28 U.S.C. §§ 1331 and 1338(a).

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7. Venue is proper in this district under 28 U.S.C. §§ 1391(b) and (c), and 1400(b), as TZero conducts business in this district and has committed, and is continuing to commit, acts of infringement in this district.

FACTUAL BACKGROUND

PULSE~LINK is a Pioneer of Ultra-Wideband Communication Technology

8. PULSE~LINK is a leading innovator in Ultra-Wideband ("UWB") communications. PULSE~LINK is the oldest UWB company focused on high-speed commercial communications, and is widely recognized as the pioneer of a broad range of UWB technologies.

9. In 2002, PULSE~LINK was the first to invent and demonstrate UWB over band limited channels such as coaxial cables—an innovation for which PULSE~LINK's Founder & CTO, John Santhoff, was later recognized by EE Times as "Innovator of the Year."

10. In October 2003, at the UWB World Conference in San Jose, California, PULSE~LINK first publicly demonstrated its UWB solution wirelessly carrying multiple streams of broadcast quality video across 20 meters (non-line of sight) at 125 Mega Bits per second ("Mbps").

11. In 2005, PULSE~LINK was the first to announce and demonstrate wireless High-Definition Multimedia Interface ("HDMI") using JPEG2000.

12. PULSE~LINK was also the first and only UWB Company to pursue whole-home High Definition networking using a combination of wired and wireless UWB.

13. In October of 2006, PULSE~LINK was the first to demonstrate simultaneous operation of Ethernet and 1394-S400 over coaxial cable.

14. The significance of this demonstration was that it simultaneously satisfied the requirements of two large trade organizations—the Digital Living Room Network Alliance ("DLNA") and the High Definition Audio Video Network Alliance ("HANA").

15. At the Consumer Electronics Show in 2007, PULSE~LINK was awarded an "Innovations Design and Engineering Award."

16. In May 2007, PULSE~LINK was again recognized and awarded with the "Red Herring 100 Award" as one of the top 100 private companies driving the future of technology.

17. PULSE~LINK is the first semiconductor company to deliver a solution capable of true room-to-room networking of interactive High Definition content from a hybrid wired/wireless chipset.

18. Devices enabled with PULSE~LINK's "CWave" UWB chipset allow High-Definition ("HD") content located in the home to be shared across the existing coax backbone, and then networked with wireless connectivity for Set-top Boxes, HDTVs, DVRs, DVD players, Gaming Devices, Media Center PCs, and other multimedia equipment. An animation of this system can be experienced at www.pulselink.net/video.

19. PULSE~LINK's "CWave" technology enables HD content to be streamed throughout the home with IPTV functionality and provides End-to-End Quality of Service, while still preserving content protection mechanisms.

20. Currently, PULSE~LINK has developed the first and only complete MAC/Baseband/RF chipset to exceed 1 Giga Bits per second ("Gbps") in UWB communications, and is the first semiconductor company to develop UWB technology for whole-home distribution of interactive high-definition multimedia content over a hybrid wired/wireless network.

PULSE~LINK's Patent No. 6,895,034

21. On May 17, 2005, United States Patent No. 6,895,034 (the "'034 Patent"), entitled "Ultra-Wideband Pulse Generation System and Method," was duly and legally issued to PULSE~LINK as assignee of the inventors, Patrick O'Neal Nunally and John Santhoff. A true and correct copy of the '034 Patent is attached hereto as Exhibit A.

22. PULSE~LINK is the owner of the '034 Patent by assignment, with full and exclusive right to bring suit to enforce it.

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23. The '034 Patent relates generally to the above technology and to the transmission, reception, and processing of Ultra-Wideband communication signals through a wired medium.

PULSE~LINK's Patent No. 7,099,368

24. On August 29, 2006, United States Patent No. 7,099,368 (the "'368 Patent"), entitled "Ultra-Wideband Communications Through a Wire Medium," was duly and legally issued to PULSE~LINK as assignee of the inventors, John Santhoff and Steve Moore. A true and correct copy of the '368 Patent is attached hereto as Exhibit B.

25. PULSE~LINK is the owner of the '368 Patent by assignment, with full and exclusive right to bring suit to enforce it.

26. The '368 Patent relates generally to the above technology and to the transmission, reception, and processing of Ultra-Wideband communication signals through a wired medium.

FIRST CAUSE OF ACTION

Patent Infringement of the '034 Patent

(35 U.S.C. §§ 271, *et seq.* against TZero)

27. PULSE~LINK refers to and incorporates paragraphs 1 through 26 inclusive, as though fully set forth herein.

28. TZero has been and is still infringing, contributing to infringement, and/or inducing others to infringe the '034 Patent by making, using, offering for sale, selling, and/or instructing users how to use infringing products that are intended to communicate using Ultra-Wideband communication technology, including, but not limited to, TZero's ZeroWire Evaluation System (also known as the "ZeroWire EVK"), 7110 Mini-PCI Card product, 7210 Mini-PCI Card product, and ZeroWireT chipsets (TZC7100 and TZC7200).

29. On information and belief, TZero threatens to continue to do the acts complained of herein, and unless restrained and enjoined, will continue to do so, all to PULSE~LINK'S irreparable damage.

30. By reason of TZero's acts alleged herein, PULSE~LINK has suffered, is

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suffering, and—unless such acts are enjoined by the Court—will continue to suffer injury to its business and property rights, for which it is entitled to damages pursuant to 35 U.S.C. § 284 in an amount to be determined at trial.

31. By reason of TZero's acts alleged herein, PULSE~LINK has suffered, is suffering, and—unless such acts are enjoined by the Court—will continue to suffer irreparable harm for which there is no adequate remedy at law, and for which PULSE~LINK is entitled to permanent injunctive relief pursuant to 35 U.S.C. § 283.

32. PULSE~LINK is informed and believes and thereon alleges that TZero's infringement of the '034 Patent under 35 U.S.C. 271 has been, and continues to be, willful and deliberate because TZero has continued its acts of patent infringement after learning of the existence of, and its infringement of, the '034 Patent, entitling PULSE~LINK to a determination that this is an exceptional case and recovery of enhanced damages and attorneys' fees pursuant to 35 U.S.C. 284.

SECOND CAUSE OF ACTION

Patent Infringement of the '368 Patent

(35 U.S.C. §§ 271, *et seq.* against TZero)

33. PULSE~LINK refers to and incorporates paragraphs 1 through 32 inclusive, as though fully set forth herein.

34. TZero has been and is still infringing, contributing to infringement, and/or inducing others to infringe the '368 Patent by making, using, offering for sale, selling, and/or instructing users how to use infringing products that are intended to communicate using Ultra-Wideband communication technology, including, but not limited to, TZero's ZeroWire Evaluation System (also known as the "ZeroWire EVK"), 7110 Mini-PCI Card product, 7210 Mini-PCI Card product, and ZeroWireT chipsets (TZC7100 and TZC7200).

35. On information and belief, TZero threatens to continue to do the acts complained of herein, and unless restrained and enjoined, will continue to do so, all to PULSE~LINK'S irreparable damage.

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36. By reason of TZero's acts alleged herein, PULSE~LINK has suffered, is suffering, and—unless such acts are enjoined by the Court—will continue to suffer injury to its business and property rights, for which it is entitled to damages pursuant to 35 U.S.C. § 284 in an amount to be determined at trial.

37. By reason of TZero's acts alleged herein, PULSE~LINK has suffered, is suffering, and—unless such acts are enjoined by the Court—will continue to suffer irreparable harm for which there is no adequate remedy at law, and for which PULSE~LINK is entitled to permanent injunctive relief pursuant to 35 U.S.C. § 283.

38. PULSE~LINK is informed and believes and thereon alleges that TZero's infringement of the '034 Patent under 35 U.S.C. 271 has been, and continues to be, willful and deliberate because TZero has continued its acts of patent infringement after learning of the existence of, and its infringement of, the '368 Patent, entitling PULSE~LINK to a determination that this is an exceptional case and recovery of enhanced damages and attorneys' fees pursuant to 35 U.S.C. 284.

PRAYER

WHEREFORE, PULSE~LINK prays for judgment against Defendants as follows:

(a) Judgment that TZero has infringed, directly and/or indirectly, PULSE~LINK's '034 Patent;

(b) Judgment that TZero has infringed, directly and/or indirectly, PULSE~LINK's '368 Patent;

(c) Judgment that TZero's infringement was willful and deliberate, therefore entitling PULSE~LINK to recover enhanced damages and attorneys' fees.

(d) A preliminary and permanent injunction prohibiting TZero, its officers, agents, servants, employees, attorneys, all parent and subsidiary corporations, all assignees and successors in interest, and all persons or entities acting in concert with TZero, from continuing in any and all acts of infringement, directly and/or indirectly, of PULSE~LINK's '034 and '368 Patents;

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(e) An award of compensatory damages under 35 U.S.C. § 284 for TZero's infringement of PULSE~LINK's '034 and '368 Patents.

(f) An award of treble the compensatory damages pursuant to 35 U.S. C. § 284 as a result of TZero's willful infringement of PULSE~LINK's '034 and '368 Patents;

(g) Judgment and an order directing TZero to pay PULSE~LINK's reasonable attorneys' fees, expenses and costs due to this being an "exceptional" case within the meaning of 35 U.S.C. § 285;

(h) Such other or further legal or equitable relief that the Court deems just and proper.

DEMAND FOR JURY TRIAL

In accordance with Rule 38(b) of the Federal Rules of Civil Procedure, PULSE~LINK demands a trial by jury on all issues so triable.

DATED: November 9, 2007

Respectfully submitted,

HELLER EHRMAN LLP

By [signature] (SRH)
JOHN BENASSI
Attorneys For Plaintiff
PULSE~LINK INCORPORATED

Heller Ehrman LLP

Exhibit A

US006895034B2

(12) **United States Patent**
Nunally et al.

(10) **Patent No.: US 6,895,034 B2**
(45) **Date of Patent: May 17, 2005**

(54) **ULTRA-WIDEBAND PULSE GENERATION SYSTEM AND METHOD**

(75) Inventors: **Patrick O'Neal Nunally**, San Diego, CA (US); **John Santhoff**, San Diego, CA (US)

(73) Assignee: **Pulse-LINK, Inc.**, Carlsbad, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 14 days.

(21) Appl. No.: **10/188,987**

(22) Filed: **Jul. 2, 2002**

(65) **Prior Publication Data**

US 2004/0005013 A1 Jan. 8, 2004

(51) **Int. Cl.**[7] **H04B 1/69**
(52) **U.S. Cl.** **375/130**; 375/257
(58) **Field of Search** 375/257, 295, 375/353, 256, 130; 342/21, 27, 82, 175

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WO WO 02/31986 A2 4/2002

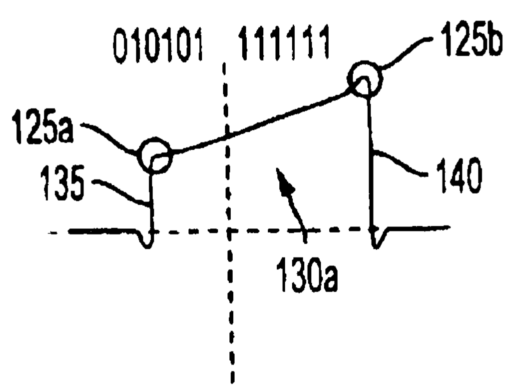
* cited by examiner

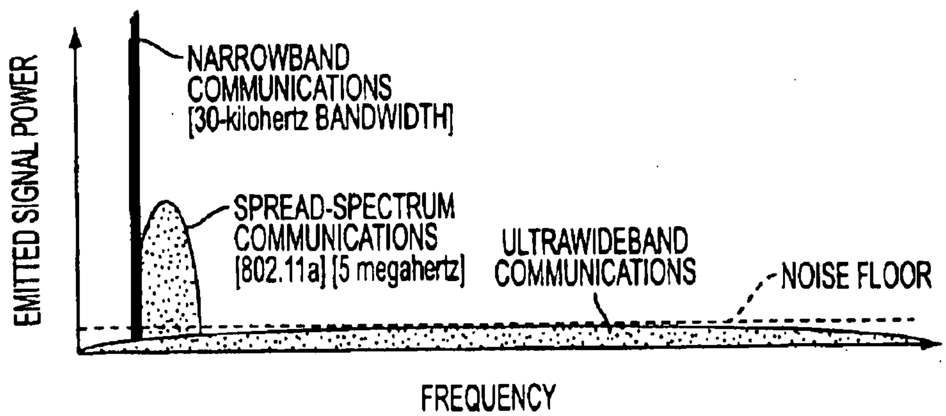
Primary Examiner—Don N. Vo
(74) *Attorney, Agent, or Firm*—Pulse-LINK, Inc.; Peter R. Martinez; Steven A. Moore

(57) **ABSTRACT**

A system and method to generate an ultra-wideband pulse is provided. One method of the present invention includes generating an ultra-wideband pulse that includes a first section representing a first data symbol, and a second section representing a second data symbol. A second method of the present invention includes generating an ultra-wideband that comprises a plurality of time bins, with each time bin comprising a data symbol that represents a multiplicity of binary digits. Another method of the present invention includes generating an ultra-wideband pulse that comprises a plurality of time bins, with each time bin representing a first data symbol. The same ultra-wideband pulse also includes an amplitude that represents a second data symbol.

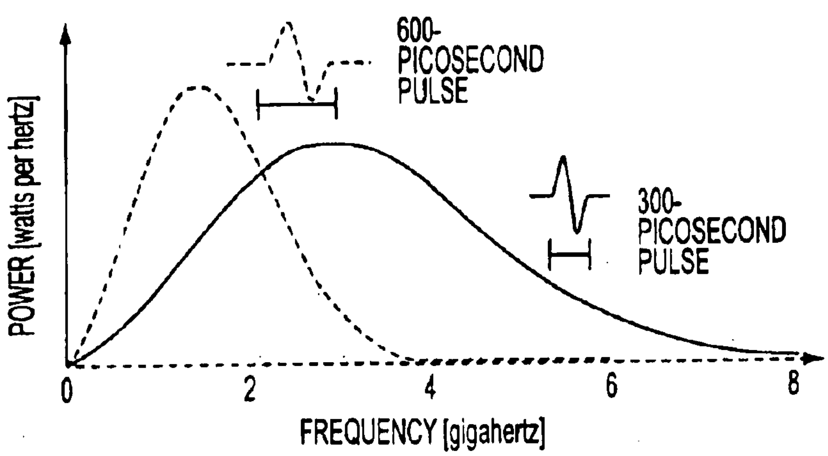
32 Claims, 8 Drawing Sheets





EMITTED SIGNAL POWER
NARROWBAND COMMUNICATIONS [30-kilohertz BANDWIDTH]
SPREAD-SPECTRUM COMMUNICATIONS [802.11a] [5 megahertz]
ULTRAWIDEBAND COMMUNICATIONS
NOISE FLOOR
FREQUENCY

FIG. 1



POWER [watts per hertz]
600-PICOSECOND PULSE
300-PICOSECOND PULSE
0
2
4
6
8
FREQUENCY [gigahertz]

FIG. 2

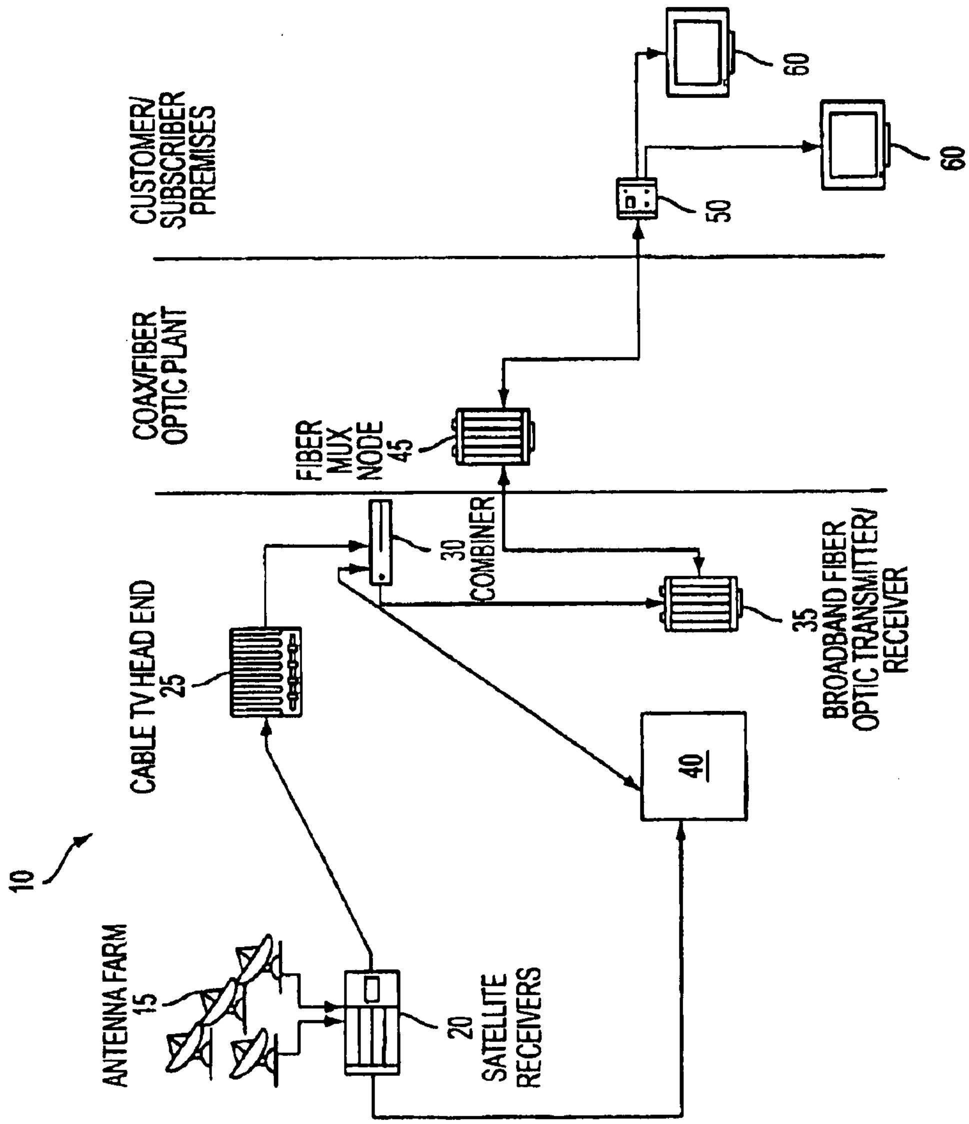
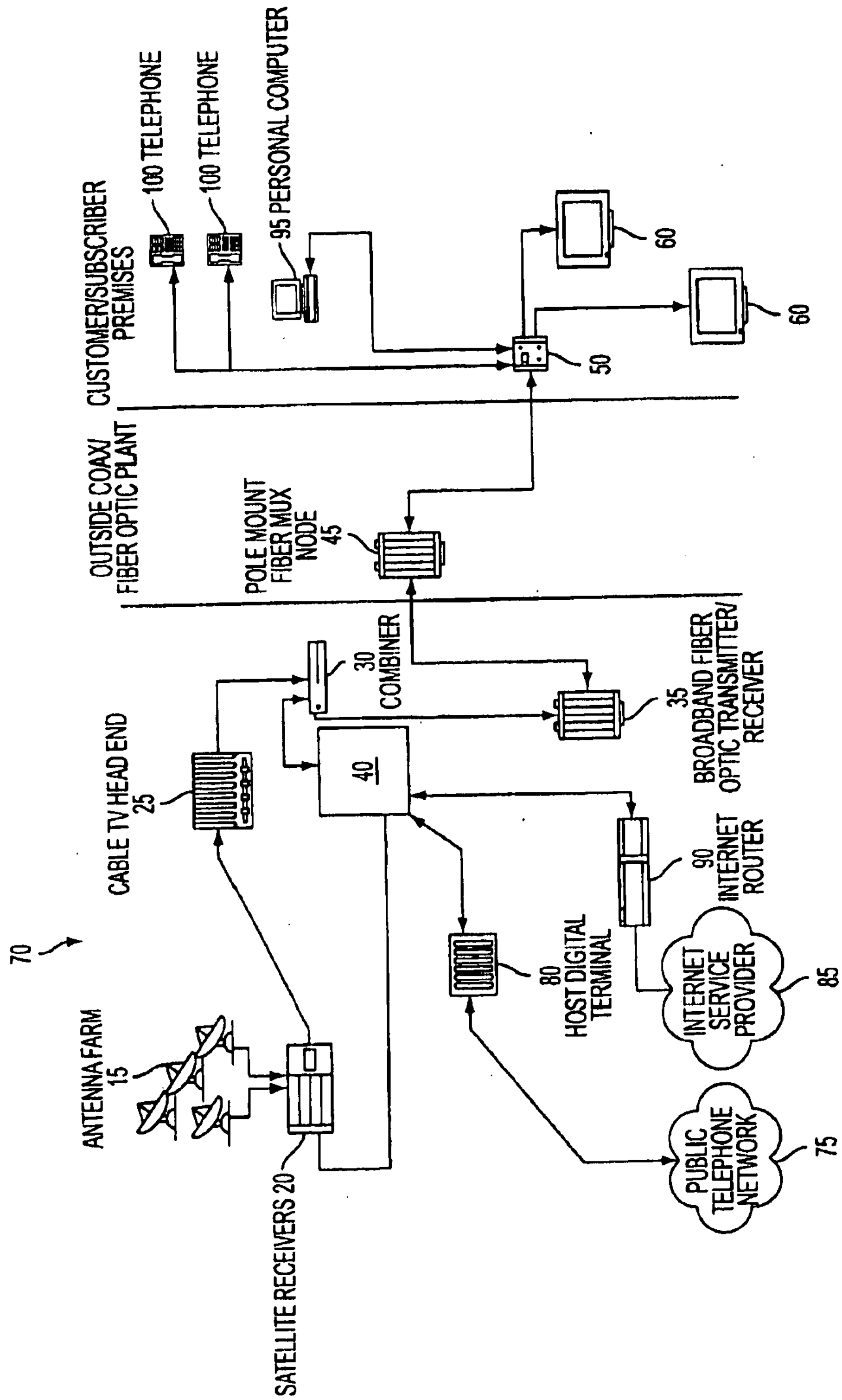
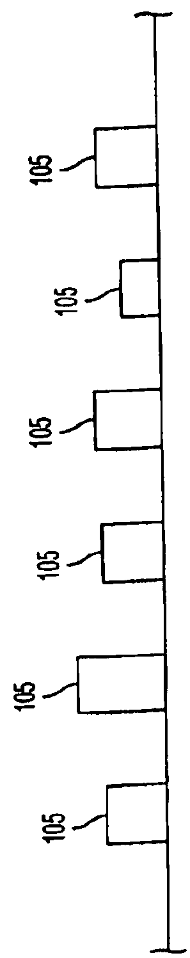

10
ANTENNA FARM
15
20
SATELLITE
RECEIVERS
CABLE TV HEAD END
25
30
COMBINER
40
35
BROADBAND FIBER
OPTIC TRANSMITTER/
RECEIVER
FIBER
MUX
NODE
45
COAX/FIBER
OPTIC PLANT
CUSTOMER/
SUBSCRIBER
PREMISES
50
60
60

FIG. 3



70
ANTENNA FARM 15
SATELLITE RECEIVERS 20
CABLE TV HEAD END 25
30 COMBINER
40
35 BROADBAND FIBER OPTIC TRANSMITTER/ RECEIVER
OUTSIDE COAX/ FIBER OPTIC PLANT
POLE MOUNT FIBER MUX NODE 45
CUSTOMER/SUBSCRIBER PREMISES
100 TELEPHONE
100 TELEPHONE
95 PERSONAL COMPUTER
50
60
60
80 HOST DIGITAL TERMINAL
90 INTERNET ROUTER
INTERNET SERVICE PROVIDER
85
PUBLIC TELEPHONE NETWORK
75

FIG. 4


105
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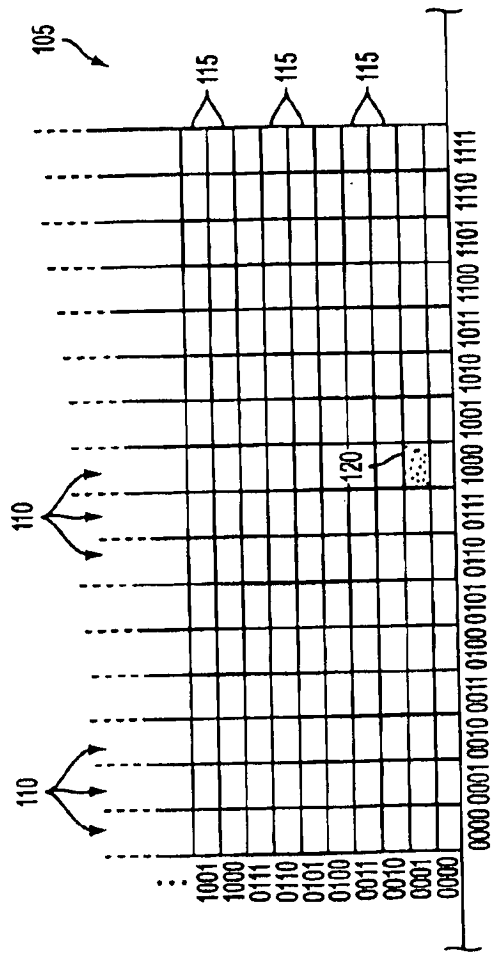
105
105
105
105

FIG. 5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115
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0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111
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0011
0100
0101
0110
0111
1000
1001

FIG. 6

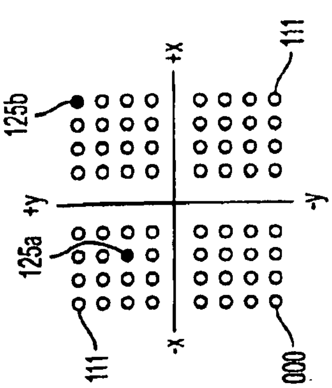

FIG. 7a

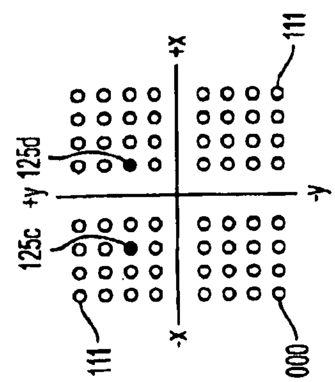

FIG. 7b

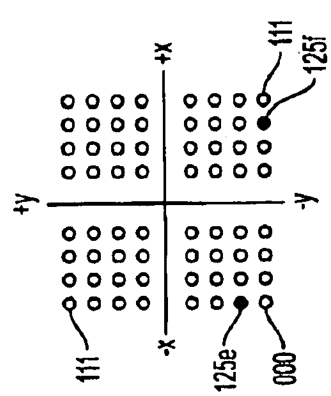

FIG. 7c

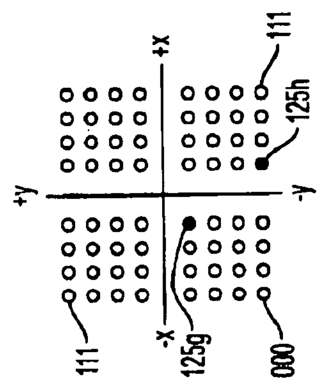

FIG. 7d

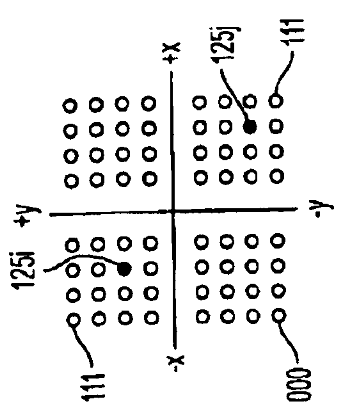

FIG. 7e

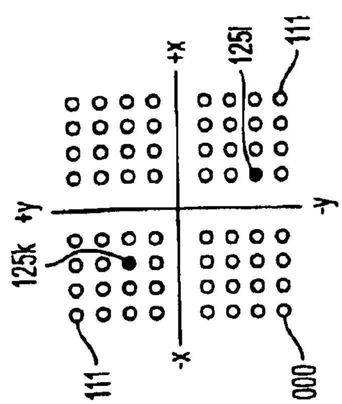

FIG. 7f

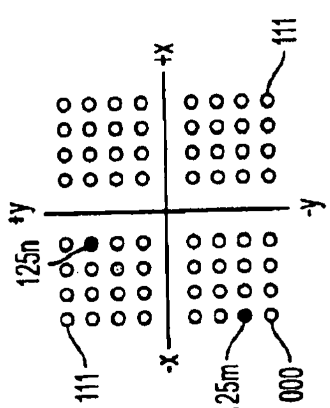

FIG. 7g

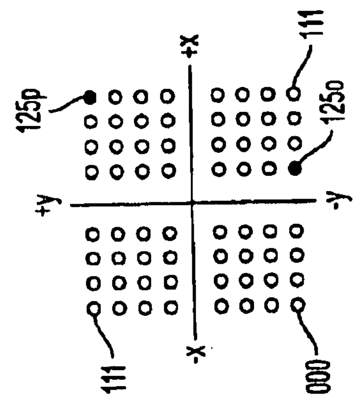

FIG. 7h

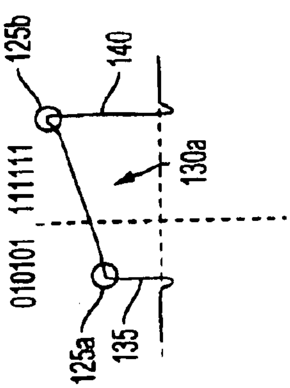

FIG. 8a

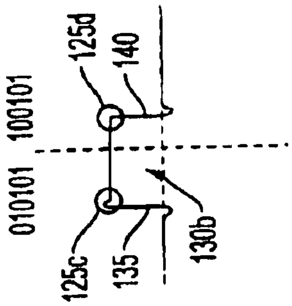

FIG. 8b

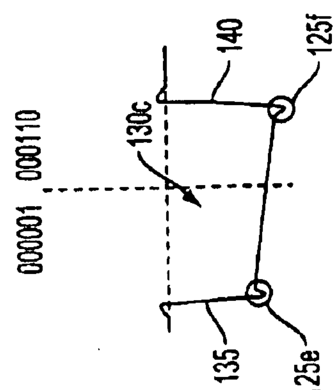

FIG. 8c

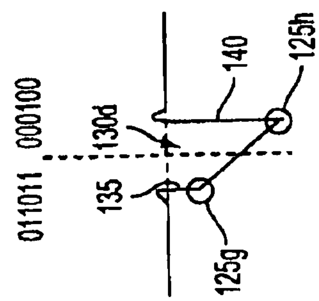

FIG. 8d

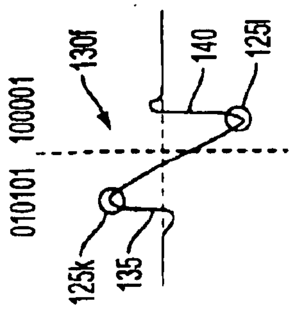

FIG. 8f

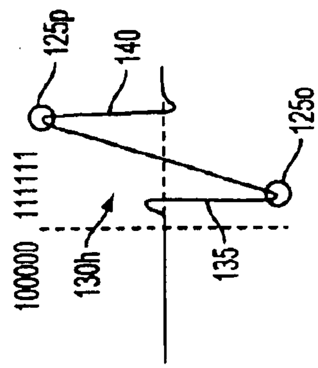

FIG. 8h

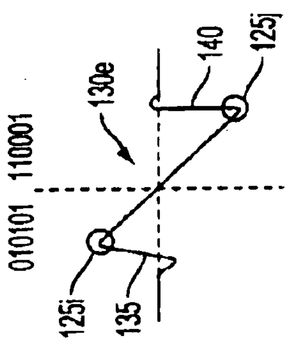

FIG. 8e

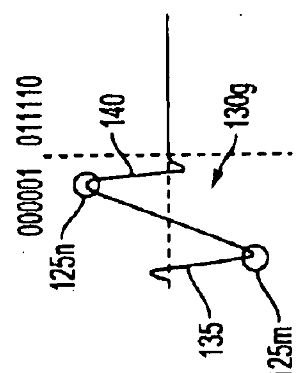

FIG. 8g

ULTRA-WIDEBAND PULSE GENERATION SYSTEM AND METHOD

FIELD OF THE INVENTION

The present invention generally relates to ultra-wideband communications. More particularly, the invention concerns a method to generate ultra-wideband pulses that convey data through a wire medium.

BACKGROUND OF THE INVENTION

The Information Age is upon us. Access to vast quantities of information through a variety of different communication systems are changing the way people work, entertain themselves, and communicate with each other. For example, as a result of increased telecommunications competition mapped out by Congress in the 1996 Telecommunications Reform Act, traditional cable television program providers have evolved into full-service providers of advanced video, voice and data services for homes and businesses. A number of competing cable companies now offer cable systems that deliver all of the just-described services via a single broadband network.

These services have increased the need for bandwidth, which is the amount of data transmitted or received per unit time. More bandwidth has become increasingly important, as the size of data transmissions has continually grown. Applications such as in-home movies-on-demand and video teleconferencing demand high data transmission rates. Another example is interactive video in homes and offices.

Other industries are also placing bandwidth demands on Internet service providers, and other data providers. For example, hospitals transmit images of X-rays and CAT scans to remotely located physicians. Such transmissions require significant bandwidth to transmit the large data files in a reasonable amount of time. These large data files, as well as the large data files that provide real-time home video are simply too large to be feasibly transmitted without an increase in system bandwidth. The need for more bandwidth is evidenced by user complaints of slow Internet access and dropped data links that are symptomatic of network overload.

Internet service providers, cable television networks and other data providers generally employ conductive wires and cables to transmit and receive data. Conventional approaches to signal (i.e. data) transmission through a transmission medium, such as a wire or cable, is to modulate the signal though the medium at a frequency that lies within the bounds at which the medium can electrically conduct the signal. Because of this conventional approach, the bandwidth of a specific medium is limited to a spectrum within which the medium is able to electrically transmit the signal via modulation, which yields a current flow. As a result, many costly and complicated schemes have been developed to increase the bandwidth in conventional conductive wire and/or cable systems using sophisticated switching schemes or signal time-sharing arrangements. Each of these methods is rendered costly and complex in part because the data transmission systems adhere to the conventional acceptance that the bandwidth of a wire or cable is constrained by its conductive properties.

Therefore, there exists a need for a method to increase the bandwidth of conventional wire networks.

SUMMARY OF THE INVENTION

The present invention provides a method to transmit ultra-wideband signals across any wire medium, whether the medium is twisted-pair wire, coaxial cable, fiber optic cable, or other types of wire media.

In one embodiment of the invention, a method of transmitting an ultra-wideband signal through a wire medium comprises generating an ultra-wideband pulse, the ultra-wideband pulse including a first section representing a first data symbol, and a second section representing a second data symbol. Another embodiment of the present invention comprises a method of transmitting an ultra-wideband signal through a wire medium that includes an ultra-wideband pulse structured to transmit data through a wire medium, with the ultra-wideband pulse comprising an amplitude that represents a first data symbol. The ultra-wideband pulse also includes a plurality of time bins, with each time bin representing a second data symbol. This embodiment ultra-wideband signal thus transmits two distinct data symbols, increasing the bandwidth of the wire media.

One feature of the present invention is that an ultra-wideband signal can be transmitted simultaneously with a traditional cable television signal, Internet connection signal or voice transmission signal. Because the ultra-wideband signal can be transmitted substantially simultaneously with the other signals, the overall bandwidth or capability of the system to transmit data is vastly increased.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of different communication methods;

FIG. **2** is an illustration of two ultra-wideband pulses;

FIG. **3** is a schematic illustration of one embodiment of an ultra-wideband communication system employing a wire medium;

FIG. **4** is a schematic illustration of a second embodiment of an ultra-wideband communication system employing a wire medium;

FIG. **5** is an illustration of exemplary ultra-wideband pulses constructed according to the present invention;

FIG. **6** is an illustration of a single ultra-wideband pulse as shown in FIG. **5**;

FIGS. **7***a*–**7***h* illustrate rectangular coordinate representations of data bits; and

FIGS. **8***a*–**8***h* illustrate ultra-wideband pulses constructed according to an alternative embodiment of the present invention, with corresponding ultra-wideband pulses constructed to transmit corresponding data bit representations, as illustrated in FIGS. **7***a*–**7***h*.

It will be recognized that some or all of the Figures are schematic representations for purposes of illustration and do not necessarily depict the actual relative sizes or locations of the elements shown.

DETAILED DESCRIPTION OF THE INVENTION

In the following paragraphs, the present invention will be described in detail by way of example with reference to the attached drawings. Throughout this description, the preferred embodiment and examples shown should be considered as exemplars, rather than as limitations on the present invention. As used herein, the "present invention" refers to any one of the embodiments of the invention described herein, and any equivalents. Furthermore, reference to various feature(s) of the "present invention" throughout this document does not mean that all claimed embodiments or methods must include the referenced feature(s).

Generally, a traditional cable television provider, a community antenna television provider, a community access television provider, a cable television provider, a hybrid fiber-coax television provider, an Internet service provider, or any other provider of television, audio, voice and/or Internet data receives broadcast signals at a central station, either from terrestrial cables, and/or from one or more antennas that receive signals from a communications satellite. The broadcast signals are then distributed, usually by coaxial and/or fiber optic cable, from the central station to nodes located in business or residential areas.

For example, community access television provider (CATV) networks are currently deployed in several different topologies and configurations. The most common configurations found today are analog signals transmitted over coaxial cable and Hybrid Fiber-Coax Systems (HFCS) that employ both fiber optic and coaxial cables. The analog coax systems are typically characterized as pure analog systems. Pure analog CATV systems are characterized by their use of established NTSC/PAL (National Television Standards Committee/Phase Alternation Line) modulation onto a frequency carrier at 6 or 8 MHz intervals.

HFCS is a combination analog—digital topology employing both coaxial (analog) and fiber optic (digital) media that typically supports digitally modulated/encoded television channels above channel **78**. According to ANSI/EIA-542-1997, in the United States, the analog channels are modulated in 6 MHz allocations on channels **2** to **78** using frequencies from 55 to 547 MHz. When using HFCS, digital channels typically start at channel **79** and go as high as **136** and occupy a frequency range from 553 to 865 MHz. In some extended HFCS systems, channel assignments can go as high as channel **158** or 997 MHz. The current ANSI/EIA-542-1997 standard only defines and assigns channels to these limits. The actual wire/cable media itself is generally capable of transmitting frequencies up to 3 GHz.

In both CATV and HFCS systems, typically the satellite downlink enters the cable company's head-end and the video, and/or other data streams are de-multiplexed out. Individual video data streams (either NTSC, MPEG, or any other suitable protocol) are extracted from the satellite downlink stream and routed to modulators specific for individual television channels. The outputs from each modulator are then combined into one broadband signal. From this point the combined channels are amplified and sent out, either by coaxial or fiber optic cable, to the customers.

In a HFCS, before the combined broadband signal leaves the head-end the broadband signal is modulated onto a fiber optic cable for distribution into the field, such as residential neighborhoods, or business districts. Modulation of the broadband signal is typically accomplished in one of two ways. In the first method the entire broadband signal is sampled and digitized using a high speed Analog to Digital Converter (ADC). To perform reliable digital sampling, the data must be sampled at a rate at least twice the highest frequency component to meet Nyquist minimum sampling requirements. To provide a higher quality data stream, the signal should be sampled at 2.5 to 4 times the highest frequency, which entails sample rates of approximately 2 to 4 GHz. A parallel to serial converter then shifts the parallel output data of the ADC into a serial format. The serial data then drives a laser diode for transmission over the fiber optic cable. The second method is broadband block conversion where the entire spectrum of the broadband signal is modulated onto the fiber optic cable.

Designated access nodes are located in neighborhoods, business districts and other areas. The access nodes contain a high speed Digital to Analog Converter (DAC) and a de-serializer. A fiber optic receiver detects the laser-modulated signal at the access node. A parallel to serial converter de-serializes the data and it is feed to the high speed DAC. The data then leaves the access node on standard 75 ohm, RG-6 or RG-8 or other suitable coax cable and is distributed to the customer's premises. Thus, at the access node, the broadband signal is extracted from the fiber optic cable and transferred to a coaxial cable that connects to individual homes, apartments, businesses, universities, and other customers. Support of multiple customers is generally accomplished by the use of distribution boxes in the field, for example, on telephone poles or at ground level. However, as the signal is continuously split at the distribution boxes, the received bandwidth is reduced and the quality of the signal is diminished, thereby diminishing the video, audio, and other data quality.

The digital channels that generally reside on CATV channels **79** and higher are fundamentally different than the analog channels that generally reside on channels **2** through **78**. The analog channels are comprised of modulated frequency carriers. The digital channels, which generally use the 6 MHz allocation system, are digitally modulated using Quadrature Amplitude Modulation (QAM). QAM is a method of combining two amplitude modulated signals into a single channel, thereby doubling the effective bandwidth. In a QAM signal, there are two carriers, each having the same frequency but differing in phase by 90 degrees. The two modulated carriers are combined for transmission, and separated after transmission. QAM **16** transmits 16 bits per signal, QAM **32**, **64**, and **256** each transmit 32, 54 and 256 bits per signal, respectively. QAM was developed to support additional video streams encoded with MPEG video compression. Conventional CATV and HFCS networks may employ QAM levels up to QAM **64** to enable up to 8 independent, substantially simultaneous MPEG video streams to be transmitted.

At the customer's location, the coaxial cable is connected to either a set-top box or directly to a television. The receiving device then de-multiplexes and de-modulates the video, audio, voice, Internet or other data. Although a television can directly receive the analog signal, a set-top box is generally required for reception of the digitally encoded channels residing on CATV channels **79** and higher.

The above-described networks, and other networks and communication systems that employ wire media, such as twisted-pair or coaxial cable, suffer from performance limitations caused by signal interference, ambient noise, and spurious noise. In these conventional wire media systems, these limitations affect the available system bandwidth, distance, and carrying capacity of the system, because the noise floor and signal interference in the wire media rapidly overcome the signal transmitted. Therefore, noise within the wire media significantly limits the available bandwidth of any wire system or network.

Generally, the conventional wisdom for overcoming this limitation is to boost the power (i.e., increase the voltage of the signal) at the transmitter to boost the voltage level of the signal relative to the noise at the receiver. Without boosting the power at the transmitter, the receiver is unable to separate the noise from the desired signal. Thus, the overall performance of wire media systems is still significantly limited by the accompanying noise that is inherent in wire media.

Increasing the available bandwidth of an established wire media network, while coexisting with the conventional data

signals transmitted through the network, represents an opportunity to leverage the existing wire media network infrastructure to enable the delivery of greater functionality. Several methods and techniques have been proposed, but they are generally computationally intense, hence costly.

The present invention may be employed in any type of network that uses wire media, in whole, or in part. That is, a network may use both wire media, such as coaxial cable, and wireless devices, such as satellites. As defined herein, a network is a group of points or nodes connected by communication paths. The communication paths may be connected by wires, or they may be wirelessly connected. A network as defined herein can interconnect with other networks and contain subnetworks. A network as defined herein can be characterized in terms of a spatial distance, for example, such as a local area network (LAN), a personal area network (PAN), a metropolitan area network (MAN), and a wide area network (WAN), among others. A network as defined herein can also be characterized by the type of data transmission technology in use on it, for example, a TCP/IP network, and a Systems Network Architecture network, among others. A network as defined herein can also be characterized by whether it carries voice, data, or both kinds of signals. A network as defined herein can also be characterized by who can use the network, for example, a public switched telephone network (PSTN), other types of public networks, and a private network (such as within a single room or home), among others. A network as defined herein can also be characterized by the usual nature of its connections, for example, a dial-up network, a switched network, a dedicated network, and a nonswitched network, among others. A network as defined herein can also be characterized by the types of physical links that it employs, for example, optical fiber, coaxial cable, a mix of both, unshielded twisted pair, and shielded twisted pair, among others.

The present invention employs a "carrier free" architecture, which does not require the use of high frequency carrier generation hardware, carrier modulation hardware, stabilizers, frequency and phase discrimination hardware or other devices employed in conventional frequency domain communication systems. The present invention dramatically increases the bandwidth of conventional networks that employ wire media, but can be inexpensively deployed without extensive modification to the existing wire media network.

The present invention provides increased bandwidth by injecting, or otherwise super-imposing an ultra-wideband (UWB) signal into the existing data signal and subsequently recovers the UWB signal at an end node, set-top box, subscriber gateway, or other suitable location. Ultra-wideband, or impulse radio, employs pulses of electromagnetic energy that are emitted at nanosecond or picosecond intervals (generally tens of picoseconds to a few nanoseconds in duration). For this reason, ultra-wideband is often called "impulse radio." Because the excitation pulse is not a modulated waveform, UWB has also been termed "carrier-free" in that no apparent carrier frequency is evident in the radio frequency (RF) spectrum. That is, the UWB pulses are transmitted without modulation onto a sine wave carrier frequency, in contrast with conventional radio frequency technology. Ultra-wideband generally requires neither an assigned frequency nor a power amplifier.

Conventional radio frequency technology employs continuous sine waves that are transmitted with data embedded in the modulation of the sine waves' amplitude or frequency. For example, a conventional cellular phone must operate at a particular frequency band of a particular width in the total frequency spectrum. Specifically, in the United States, the Federal Communications Commission has allocated cellular phone communications in the 800 to 900 MHz band. Cellular phone operators use 25 MHz of the allocated band to transmit cellular phone signals, and another 25 MHz of the allocated band to receive cellular phone signals.

Another example of a conventional radio frequency technology is illustrated in FIG. 1. 802.11a, a wireless local area network (LAN) protocol, transmits radio frequency signals at a 5 GHz center frequency, with a radio frequency spread of about 5 MHz.

In contrast, a UWB pulse may have a 1.8 GHz center frequency, with a frequency spread of approximately 4 GHz, as shown in FIG. 2, which illustrates two typical UWB pulses. FIG. 2 illustrates that the narrower the UWB pulse in time, the higher its center frequency and the broader the spread of its frequency spectrum. This is because frequency is inversely proportional to the time duration of the pulse. A 600 picosecond UWB pulse will have about a 1.8 GHz center frequency, with a frequency spread of approximately 4 GHz. And a 300 picosecond UWB pulse will have about a 3 GHz center frequency, with a frequency spread of approximately 8 GHz. Thus, UWB pulses generally do not operate within a specific frequency, as shown in FIG. 1. And because UWB pulses are spread across an extremely wide frequency range, UWB communication systems allow communications at very high data rates, such as 100 megabits per second or greater.

Further details of UWB technology are disclosed in U.S. Pat. No. 3,728,632 (in the name of Gerald F. Ross, and titled: Transmission and Reception System for Generating and Receiving Base-Band Duration Pulse Signals without Distortion for Short Base-Band Pulse Communication System), which is referred to and incorporated herein in its entirety by this reference.

Also, because the UWB pulse is spread across an extremely wide frequency range, the power sampled at a single, or specific frequency is very low. For example, a UWB one-watt signal of one nano-second duration spreads the one-watt over the entire frequency occupied by the pulse. At any single frequency, such as at the carrier frequency of a CATV provider, the UWB pulse power present is one nano-watt (for a frequency band of 1 GHz). This is well within the noise floor of any wire media system and therefore does not interfere with the demodulation and recovery of the original CATV signals. Generally, the multiplicity of UWB pulses are transmitted at relatively low power (when sampled at a single, or specific frequency), for example, at less than −30 power decibels to −60 power decibels, which minimizes interference with conventional radio frequencies. However, UWB pulses transmitted through most wire media will not interfere with wireless radio frequency transmissions. Therefore, the power (sampled at a single frequency) of UWB pulses transmitted though wire media may range from about +30 dBm to about −90 dBm.

For example, a CATV system generally employs a coaxial cable that transmits analog data on a frequency carrier. Generally, amplitude modulation (AM) or QAM (discussed above) are used to transmit the analog data. Since data transmission employs either AM or QAM, UWB signals can coexist in this environment without interference. In AM, the data signal M(t) is multiplied with a cosine at the carrier frequency. The resultant signal y(t) can be represented by:

$$y(t)=m(t)\mathrm{Cos}(\omega_c t)$$

In a QAM based system multiple carrier signals are transmitted at the same carrier frequency, but at different phases.

This allows multiple data signals to be simultaneously carried. In the case of two carriers, an "in phase" and "quadrature" carriers can carry data signals Mc(t) and Ms(t). The resultant signal y(t) can be represented as:

$$y(t)=Mc(t)\mathrm{Cos}(\omega_c t)+Ms(t)\mathrm{Sin}(\omega_c t)$$

However, as discussed above, an UWB system transmits a narrow time domain pulse, and the signal power is generally evenly spread over the entire bandwidth occupied by the signal. At any instantaneous frequency, such as at the AM or QAM carrier frequency, the UWB pulse power present is one nano-watt (for a frequency band of 1 GHz). This is well within the noise floor of any wire media system and therefore does not interfere with the demodulation and recovery of the original AM or QAM data signals.

Wire media communication systems suffer from performance limitations caused by signal interference, ambient noise, and spurious noise. These limitations affect the available bandwidth, distance, and carrying capacity of the wire media system. With wired communication systems, the noise floor and signal interference in the wire media rapidly overcome the transmitted carrier signal. This noise on the wire media is a significant limitation to the ability of the system to increase bandwidth. UWB technology makes use of the noise floor to transmit data, without interfering with the carrier signal. Moreover, UWB transmitted through a wire medium has distinct advantages over its use in a wireless environment. In a wire environment there are no concerns with intersymbol interference, and there are no concerns relating to multi-user interference.

For example, CATV channels typically occupy 6 MHz in the US and 8 MHz in Europe. These channels are arranged in a re-occurring pattern beginning at approximately 50 MHz and dependent on the CATV system, extend upward to 550 MHz, 750 MHz, 870 MHz, 1 GHz and higher. The present invention is capable of injecting UWB pulses into the existing CATV infrastructure. These UWB signals do not interfere or degrade existing frequency domain signals. Additionally, the UWB signals can carry vast amounts of information with digital meaning in the time domain.

The present invention provides an apparatus and method to enable any wire media network to augment their available bandwidth. Preferably, this additional bandwidth is obtained by introducing UWB signals into the existing data transmission chain prior to broadcast from the system operator's head-end. As shown in FIGS. **3** and **4**, the head-end may include several components, such as the antenna farm **15**, the satellite receivers **20**, the channel modulator **25**, the combiner **30**, and the fiber optic transmitter/receiver **35**. Alternatively, UWB signals may be introduced into the wire media network at other locations, such as at the Internet router **90** or at the host digital terminal **80**, or at any other suitable location.

In like fashion, cable system operators can receive more data from individual subscribers by introducing subscriber-generated data into existing upstream channels. The present invention provides UWB communication across fiber optic and coaxial cable, twisted pair wires, or any other type of conductive wire. A wire media network will be able to both transmit and receive digital information for the purposes of telephony, high-speed data, video distribution, video conferencing, wireless base operations and other similar purposes.

Referring to FIG. **3**, the wired ultra-wideband communication system **10** is configured to transmit ultra-wideband signals over an existing network or system that includes wire media. For example, the wired ultra-wideband (UWB) system **10** may transmit UWB signals over an existing community access television network (CATV), an optical network, a cable television network, a community antenna television network, a hybrid fiber-coax television network, an Internet service provider network, a PSTN network, a WAN, LAN, MAN, PAN, TCP/EP network, a college campus, town, city, or any other type of network as defined above, that employs wire media, in whole or in part.

One embodiment of the wired UWB communication system **10** is illustrated in FIG. **3**. An antenna farm **15** receives audio, video and data information from one or more satellites (not shown). Additional data may be received by terrestrial cables and wires and by terrestrial wireless sources, such as a multichannel multipoint distribution service (MMDS). The data is then forwarded to the satellite receivers **20** that demodulate the data into separate audio, video and data streams. This information is forwarded to the channel modulators **25** that receive the program signals, such as CNN or MTV. The channel modulators **25** mix each signal with a radio frequency (RF) and assign a station number (such as 2 to 99) that each program will be received on by subscribers.

The multiple RF signals are then forwarded to a combiner **30** that combines the multiple signals into a single output. That is, the combiner **30** receives the program signals from the channel modulators **25** and combines them onto a single coax cable and forwards the signal to the fiber optic transmitter/receiver **35**. The above-described arrangement and function of channel modulators **25** and combiners **30** may vary with each type of wire media network.

Additional audio, video, or other data signals received from either the antenna farm **15** or from terrestrial sources such as fiber optic or coaxial cables can be routed from the satellite receiver **20** to the service provider ultra-wideband (UWB) device **40**. The service provider UWB device **40** converts the audio, video, or other data signals received from the satellite receiver **20** into a multiplicity of UWB electromagnetic pulses. One embodiment of the service provider UWB device **40** may function as a transmitter and as a receiver, to both transmit and receive UWB pulses.

The service provider UWB device **40** may include several components, including a controller, digital signal processor, an analog coder/decoder, a waveform generator, an encoder, static and dynamic memory, data storage devices, a receiver, an amplifier, an interface, one or more devices for data access management, and associated cabling and electronics. One or more of the above-listed components may be co-located or they may be separate devices, and the service provider UWB device **40** may include some, or all of these components, other necessary components, or their equivalents. The controller may include error control, and data compression functions. The analog coder/decoder may include an analog to digital conversion function and vice versa. The data access management device or devices may include various interface functions for interfacing to wire media such as phone lines and coaxial cables. Alternative embodiments of the UWB device **40** may employ hard-wired circuitry used in place of, or in combination with software instructions. Thus, embodiments of the UWB device **40** are not limited to any specific combination of hardware or software.

The digital signal processor in the service provider UWB device **40** modulates the audio, video, or other data signals received from the satellite receiver **20** into a multiplicity of UWB electromagnetic pulses, and may also demodulate UWB pulses received from the subscriber. As defined herein, modulation is the specific technique used to encode

the audio, video, or other data into a multiplicity of UWB pulses. Because UWB does not use a conventional carrier wave, the transmitted pulses, or waveforms themselves must contain the information being communicated. That is, the UWB pulses themselves contain the desired information.

For example, the digital signal processor and/or waveform generator may modulate the received audio, video, or other data signals into a multiplicity of UWB pulses that may have a duration that may range between about 0.1 nanoseconds to about 100 nanoseconds, and may be transmitted at relatively low power, for example, at less than −10 power decibels to −60 power decibels, as measured at a single frequency.

The UWB pulse duration and transmitted power may vary, depending on several factors. Different modulation techniques employ different UWB pulse timing, durations and power levels. The present invention envisions several different techniques and methods to transmit an UWB signal across a wire medium. One embodiment, may for example, may transmit the UWB signal in a fashion similar to that described in U.S. patent application titled, "ENCODING AND DECODING ULTRA-WIDEBAND INFORMATION," Ser. No. 09/802,590 (in the name of John H. Santhoff and Rodolfo T. Arrieta), which is referred to and incorporated herein in its entirety by this reference.

Other envisioned modulation techniques include On-Off Keying that encodes data bits as pulse (1) or no pulse (0), and Binary Phase-Shift Keying (BPSK), or bi-phase modulation. BPSK modulates the phase of the signal (0 degrees or 180 degrees), instead of modulating the position.

FIGS. 5–6 illustrate three types of modulation techniques employed by the present invention: pulse amplitude modulation (PAM), pulse position modulation (PPM), and a combined form of PAM and PPM, which will be called PQAM. FIG. 5 illustrates several UWB pulses **105**. PAM encodes or designates data in the amplitude of the UWB pulse. As illustrated, each UWB pulse **105** may have a specific amplitude, or height **115**. The amplitude **115** of each UWB pulse **105** can designate, or represent a specific bit value. For example, as shown in FIG. 6, the amplitude **115** of an UWB pulse **105** may be varied by specific increments with each increment designating a different bit value. Specifically, as shown, in part, in FIG. 6, the UWB pulse **105** has 16 discrete amplitudes **115**. The first discrete amplitude **115** designates a bit value of 0000, with the second discrete amplitude **115** designating a bit value of 0001, and the third discrete amplitude **115** designating a bit value of 0010. The bit value may vary. For example, each specific amplitude **115** of the UWB pulse **105** may designate 3 bits, 4 bits (shown in FIG. 6), 8, 16, 32, 64, 128, 256 or 512 discrete bits. In practice, for example, an UWB pulse train may include a multiplicity of pulses, with each pulse having a different amplitude **115**, representing a different bit value, as shown in FIG. 5.

In addition, the number of discrete amplitudes **115** may vary. For example, one embodiment of the present invention may employ 32 different amplitudes **115**. If 5 bits were encoded in each pulse, then a PAM32 modulation method would allow 100 million pulses, or symbols per second to carry 500 million bits per second. This number can be realized because in an average UWB pulse recurrent frequency of 100 Mhz there are 100 million symbols transmitted per second. If each symbol carries 5 bits, 500 million bits per second can be transmitted.

An alternative modulation technique, of pulse position modulation (PPM) constructed according to the present invention for transmitting UWB pulses through a wire medium is also illustrated in FIG. 6. Each UWB pulse **105** is divided into discrete time bins **110**. FIG. 6 illustrates a UWB pulse **105** that includes **16** discrete time bins **110**. Each time bin **110** represents a specific bit value. For example, as illustrated, a first time bin **110** may represent a bit value of 0000 and an adjacent time bin **110** may represent a bit value of 0001. When the UWB pulse **105** is received at a UWB receiver, the pulse is sampled at a designated time bin **110** and the representative bit value is obtained. In this fashion, a representation of any number of bits can be transmitted with each UWB pulse **105**. For example, a specific time bin may represent 3, 4, 8, 16, 32, 64, 128, 256 or more bits. The above-described PPM method transmitting 4 bits per pulse, would carry 400 million bits per second, with a UWB pulse rate of 100 MHz. Alternative embodiments of the present invention may employ more, or less than 16 discrete time bins **110**. For example, the number of time bins may range from 3 to 256 or more time bins **110**.

Also illustrated in FIG. 6 is an alternative modulation technique, the so-called PQAM, constructed according to the present invention. This alternative modulation scheme comprises a UWB pulse **105** that is modulated to include specific time bins **110** as well as specific amplitudes **115**. This modulation scheme allows the transmission of a bit value that represents twice the number of bits than some of the above-described modulation methods. By combining the detected arrival time (PPM) and the detected amplitude (PAM), PQAM can carry 8 bits of information per pulse, when PPM and PAM are each transmitting 4 bits. Thus, PQAM is capable of transmitting 800 million bits per second, with a UWB pulse transmission rate of 100 MHz.

Specifically, as illustrated in FIG. 6, PQAM includes a time bin value **110** as well as a pulse amplitude **115** value. In one embodiment, an UWB receiver will receive a UWB pulse **105** and obtain a bit value assigned to a specific time bin **110** as well as a bit value assigned to a specific amplitude **115**. For example, inter-pulse location **120** includes a time bin **110** bit value of 1001 and an amplitude **115** bit value of 0001. Therefore, a representation, or symbol corresponding to 8 bits (10010001) is transmitted by a single UWB pulse **105**. Alternative UWB pulses **105** employing this modulation method may transmit a symbol or representation that corresponds to 16, 32, 64, 128, 256 or more bits in a single UWB pulse **105**.

Referring to FIGS. 7*a*–7*h* and 8*a*–8*h*, an alternative UWB modulation scheme is illustrated. FIGS. 7*a*–7*h* illustrate rectangular coordinate representations of different data bits, or data bit symbols **125**. Each circle represents a specific bit value. For example, symbol **125*a*** represents a bit value of 010101. This bit value is determined by combining the bit value assigned to the X-axis as well as the Y-axis for each circle. For example, the circle located in the lower left corner of the -X and -Y region has a bit value of 000. The adjacent circle is assigned a bit value of 001 and the circle adjacent to that one along the same row is designated 010. The designation of bit values uses the conventional binary numbering system. Referring again to FIGS. 7*a*–7*h*, only three bits are assigned to each axis and therefore the bit value for symbol **125*b*** is 111111, the bit value for symbol **125*c*** is 010101, the bit value for symbol **125*d*** is 100101, the bit value for symbol **125*e*** is 000001, the bit value for symbol **125*f*** is 000110, the bit value for symbol **125*g*** is 011011, and the bit value for symbol **125*h*** is 000100.

Alternative embodiments of the present invention may assign 4, 8, 16, 32, 128, 256 or 512 bits to each circle on each axis of the rectangular coordinate representation. For example, if 16 bits are assigned to each location on the

X-axis, and 16 bits are assigned to each location on the Y-axis, then each data bit symbol **125** would represent 32 bits.

Now referring to FIGS. *8a*–*8h*, a sloped UWB pulse **130** is illustrated. The sloped UWB pulse **130***a* includes a first section, or edge **135** and a second section, or edge **140**. The height of the first section **135** corresponds to the bit symbol **125***a*, illustrated in FIG. *7a*. Similarly, the height of the second section **140** corresponds to the bit symbol **125***b*, illustrated in FIG. *7a*. Thus, a single sloped UWB pulse **130** can include two bit symbols **125**. And, as shown in FIG. *8a*, each bit symbol represents, in this embodiment, six specific bits. Therefore, each sloped UWB pulse **130** can transmit two bit symbol **125** representations, totaling 12 bits.

In comparison to the pulse modulation scheme illustrated in FIG. **6**, the sloped UWB pulse **130** can transmit twice the number of symbols and thus twice the amount of represented bits. For example, if each axis of the rectangular coordinate representation in FIG. *7a* included four bits, then the total number of bits transmitted by data bit symbol **125***a* would be 8 bits. Thus, the first section **135** of the sloped UWB pulse **130**, shown in FIG. *8a*, would include a bit symbol **125***a* that represents 8 bits. The second section **140** would also include a bit symbol **125***b* that represents 8 bits. Thus, the combined represented bit data from one sloped UWB pulse **130** is 16 bits. This is twice the number of bits transmitted by the single UWB pulse **105** illustrated in FIG. **6**. This "sloped amplitude modulation" (SLAM) method of the present invention doubles the amount of data transmitted per UWB pulse. Therefore, twice the amount of data can be transmitted without increasing the pulse repetition frequency or energy level of the UWB pulse train.

As shown in FIG. *8b*, sloped UWB pulse **130** must not always include a slope between the first section **135** and the second section **140**. In this instance, sloped UWB pulse **130***b* includes bit symbols **125***c* and **125***d* that have similar amplitudes or heights. In this case, bit symbol **125***c* represents bits 010101 and bit symbol **125***d* represents bits 100101, as illustrated in FIG. *7b*. In addition, a sloped UWB pulse **130** may also be a negative pulse, as illustrated in FIGS. *8c* and *8d*. Sloped UWB pulse **130***c* includes bit symbols **125***e* and **125***f*. These bit symbols represent bits 000001 and 000110, respectively, as illustrated in FIG. *7c*. Sloped UWB pulse **130***d*, shown in FIG. *8d*, includes bit symbol **125***g* (011011) and bit symbol **125***h* (000100).

Moreover, other sloped UWB pulses **130** may include UWB pulses with first sections **135** that are positive and second sections **140** that are negative, or vice-versa, as shown in FIGS. *8e*–*8h*. Specifically, sloped UWB pulse **130***e*, shown in FIG. *8e*, includes bit symbol **125***i* and bit symbol **125***j* that represent bit values, illustrated in FIG. *7e*, of 010101 and 110001, respectively. Sloped UWB pulse **130***f*, illustrated in FIG. *8f*, includes a positive first section **135** and a negative second section **140** that include bit symbols **125***k* (010101) and **125***l* (100001), respectively. FIG. *8g* illustrates a sloped UWB pulse **130***g* that includes a negative first section **135** and a positive second section **140**. Bit symbol **125***m* represents bits 000001 and bit symbol **125***n* represents bits 011110, as shown in FIG. *7g*. Similarly, as shown in FIG. *8a*, sloped UWB pulse **130***h* includes bit symbol **125***o* and bit symbol **125***p* that represent bit streams 100000 and 111111, respectively, as illustrated in FIG. *7h*. The above-described SLAM method of the present invention can provide twice the bit symbol rate of conventional modulation techniques, with no additional bandwidth consumption. The expected bandwidth increase for a conventional CATV or HFCS system will be 100's of megabits per

second, which will allow cable providers, and other wire networks to provide new services without adding costly infrastructure upgrades.

It will be appreciated that other modulation techniques, currently existing or yet to be conceived, may also be employed.

One possible modulation technique will optimize signal coexistence and pulse reliability by controlling transmission power, pulse envelope shape and Pulse Recurrent Frequencies (PRF). Both pseudo-random and fixed PRFs may be used, with the knowledge that a fixed PRF may create a "carrier-like frequency," which it and its higher order harmonics may interfere with the data carried in conventional RF carrier channels. However, with a pseudo-random PRF the difficulties encountered with a fixed PRF are usually avoided. One embodiment of a pseudo-random PRF modulation technique may include a UWB pulse envelope that is shaped to pre-amplify and compensate for high frequency components that the wire media may naturally attenuate. UWB pulse envelope shaping has the additional advantage of controlling the power spectral density of the transmitted data stream.

Several advantages exist when transmitting UWB pulses through wire media as opposed to transmitting UWB pulses through a wireless medium. Wireless UWB transmissions must consider such issues as Inter-Symbol Interference (ISI) and Multi-User Interference (MUI), both of which can severely limit the bandwidth of UWB transmissions. Some modulation techniques such as Pulse Amplitude Modulation (PAM), which offer the ability for high bit densities are not effective at long wireless distances. Errors can arise in the interpretation of PAM pulses that have been transmitted long wireless distances (the so-called ISI problem). Pulse position modulation is also prone to errors when transmitted wirelessly. Reflections from objects in the vicinity of the transmitter and receiver can cause a pulse that was supposed to be at the beginning of a time window to appear at the end of the time window, or even in the time window of a subsequent pulse. This "multipath" problem effects the integrity of the data transmission. And, if a pulse cannot be interpreted correctly, the bits associated with the pulse cannot be reliably obtained, lowering bandwidth.

These, and other issues, do not apply to UWB pulses transmitted over wire media. Multipath and ISI issues do not arise and there are no propagation delay problems present in a wire medium. Therefore, the above-described modulation technologies, which until now have been used for wireless communications, can be implemented much more effectively in a wire medium. Because of the signal transmission advantages inherent in wire media, it is estimated that an ultra-wideband system may be able to transmit data across a wire medium in a range from 100 Mbit/second to 1 Gbit/second. This data rate will ensure that the bandwidth requirements of any service provider can be met.

A preferred embodiment of the service-provider UWB device **40** will spread the signal energy of the UWB data stream across the a bandwidth that may ranger from 50 MHz to approximately 870 MHz or as discussed above, to 1 GHz, or higher. This will ensure that the signal energy present at any frequency is significantly below the normal noise floor for that frequency band, further ensuring coexistence with conventional RF carrier data.

For example, a UWB pulse would have a duration of about 1 nano-second in a UWB data stream that has a 1 GHz bandwidth. Alternatively, the UWB pulse duration would be tailored to match the available frequency of the specific network. For a CATV or HFCS network located in the

United States, an ideal UWB pulse would generally be about 0.5 to 2 nano-seconds in duration. This is because a conventional CATV or HFCS network located in the United States typically utilizes a maximum frequency of approximately 870 MHz, but has the capacity to utilize up to 1 GHz. This bandwidth allows for a 1 to 2 nano-second pulse duration. A narrow pulse width is preferred because more pulses can be transmitted in a discrete amount of time. Pulse widths of up to 2 nano-seconds may be employed to guarantee pulse integrity throughout digitization, transmission, reception and reformation at the UWB subscriber device **50**. Generally, an idealized pulse width would be calculated based on the frequency response of the specific wire media system.

Referring to FIG. **3**, the multiplicity of generated UWB pulses are sent from the service-provider UWB device **40** to the combiner **30**, which combines the UWB pulses with the conventional RF carrier signals. One method to accomplish this task is to couple a wire carrying the conventional RF carrier signals to a standard coaxial splitter. A second wire carrying the UWB pulses is also coupled to the standard coaxial splitter. The combined signals are forwarded to the fiber optic transmitter/receiver **35**. The fiber optic transmitter/receiver **35** converts both the multiplicity of UWB pulses and the conventional RF carrier signals received from the combiner **30** into a corresponding optical signal. The optical signal generator can be either a light-emitting diode, solid state laser diode, or other suitable device. The optical signal is then distributed on fiber optic cables to residential neighborhoods, business districts, universities, colleges or other locations for distribution to subscribers and customers. Other methods and techniques for combining a UWB pulse stream and a conventional RF carrier signal stream may also be employed. For example, the UWB pulse stream my be sent directly to the fiber optic transmitter/receiver **35**, which will then combine the two signals.

Shown in FIG. **3**, a fiber multiplexer node **45** may be located at any one of the locations described above. The optical signals are received by the multiplexer **45** and are converted back to the combined conventional RF carrier and UWB pulsed signals. The combined signals are forwarded to a subscriber UWB device **50**. The subscriber UWB device **50** can be considered a gateway or router that provides access to the combined signals.

One embodiment of the subscriber UWB device **50** will demodulate the multiplicity of UWB electromagnetic pulses back into a conventional RF carrier signal. The subscriber UWB device **50** may include all, some or additional components found in the service provider UWB device **40**. In this manner, additional bandwidth will be available to the wire media network to provide the additional data and functionality demanded by the customer.

An alternative embodiment of the present invention is illustrated in FIG. **4**. A full service wired UWB communication system **70** is structured to allow for extremely high data rate transmission of video, telephone, internet and audio signals.

The full service UWB system **70** receives audio, video and data information from an antenna farm **15** or from terrestrial sources such as fiber optic or coaxial cables. These signals are forwarded to the satellite receivers **20** as described above with reference to the wired UWB communication system **10**. In addition, signals from a public telephone network **75** are received by a host digital terminal **80**. The host digital terminal **80** modulates multiple voice signals into two-way upstream and downstream RF signals. The voice signals from the host digital terminal **80** are forwarded to the service provider UWB device **40**.

An internet service provider **85** forwards internet data to the internet router **90**. The internet router **90** generates packets, such as TCP/IP packets, which are forwarded to the service provider UWB device **40**.

The service provider UWB device **40** modulates the internet data, the telephony data and the data received from the satellite receivers **20** into a multiplicity of electromagnetic pulses, as described above, and forwards the pulses to the combiner **30**. The combiner combines the UWB pulses with the conventional RF carrier signals and forwards the combined signal to the fiber optic transmitter/receiver **35**. The signals are then converted into an optical signal by either a light emitting diode, solid state laser diode, or other suitable device. The optical signal is then distributed to the fiber multiplexer node **45** located within business districts, residential neighborhoods, universities, colleges and other areas.

The fiber multiplexer node **45** receives the fiber optic signal and converts them back to the combined conventional RF carrier and UWB pulsed signals. The combined signals are forwarded to a subscriber UWB device **50**. The subscriber UWB device **50** can be considered a gateway or router that provides access to the combined signals. The subscriber UWB device **50** demodulates the multiplicity of UWB electromagnetic pulses into RF signals and forwards the RF signals to appropriate locations such as televisions, personal computers or telephones. Alternative embodiment subscriber UWB devices **50** may be located adjacent to televisions sets similar to a set-top box and used to transmit on-demand movies, internet access or pay-per-view programs. Yet another embodiment of the present invention may include a UWB device **50** that may be located within a television set, or computer. The UWB device **50** is constructed to convert and distribute data to computers, network servers, digital or subscription televisions, interactive media devices such as set-top boxes and telephone switching equipment.

The subscriber UWB device **50** may also be configured to transmit UWB pulses wirelessly to provide audio, video, and other data content to personal computers, televisions, PDAs, telephones and other devices. For example, UWB device **50** may include the necessary components to transmit and receive UWB or conventional RF carrier signals to provide access to interfaces such as PCI, PCMCIA, USB, Ethernet, IEEE1394, or other interface standards.

The present invention will also allow for data to be transmitted "upstream" toward the service provider. For example, a conventional CATV or HFCS network reserves frequencies below 50 MHz for upstream traffic. One embodiment of the present invention may include a band-pass filter with stop-bands above 1 GHz, and below 50 MHz to ensure attenuation of UWB pulses so as not to interfere with upstream traffic. These filters also serve the purpose of limiting potential inter-modulation distortion that could be introduced by the UWB pulses.

Alternative embodiments of the present invention may transmits UWB pulses through traditional telephone wires. Depending upon the provider, whether they be a local or long distance carrier, an UWB transmitter/receiver can be located in a regional center, sectional center, primary center, toll center, end-office, or their equivalents.

The present invention of transmitting ultra-wideband signals across a wire medium can employ any type of wire media. For example, the wire media can include optical fiber ribbon, fiber optic cable, single mode fiber optic cable,

multi-mode fiber optic cable, plenum wire, PVC wire, coaxial cable, or any other electrically conductive or optically conductive media.

In addition, the wire media can include twisted-pair wiring, whether shielded or unshielded. Twisted-pair wire may consist of "pairs" of color-coded wires. Common sizes of twisted-pair wire are 2 pair, 3 pair, 4 pair, 25 pair, 50 pair and 100 pair. Twisted-pair wire is commonly used for telephone and computer networks. It comes in ratings ranging from category 1 to category 7. Twisted-pair wiring also is available unshielded. That is, the wiring does not have a foil or other type of wrapping around the group of conductors within the jacket. This type of wiring is most commonly used for wiring for voice and data networks. The foregoing list of wire media is meant to be exemplary, and not exclusive.

As described above, the present invention can provide additional bandwidth to enable the transmission of large amounts of data over an existing wire media network, whether the wire media network is a Internet service provider, cable television provider, or a computer network located in a business or university. The additional bandwidth can allow consumers to receive the high speed Internet access, interactive video and other features that they are demanding.

Thus, it is seen that an apparatus and method for transmitting and receiving ultra-wideband signals through a wire medium is provided. One skilled in the art will appreciate that the present invention can be practiced by other than the above-described embodiments, which are presented in this description for purposes of illustration and not of limitation. The description and examples set forth in this specification and associated drawings only set forth preferred embodiment(s) of the present invention. The specification and drawings are not intended to limit the exclusionary scope of this patent document. Many designs other than the above-described embodiments will fall within the literal and/or legal scope of the following claims, and the present invention is limited only by the claims that follow. It is noted that various equivalents for the particular embodiments discussed in this description may practice the invention as well.

What is claimed is:

1. A method of transmitting data through a wire medium, comprising the steps of:

providing the wire medium;

generating an ultra-wideband pulse, the ultra-wideband pulse including a first section representing a first data symbol, and a second section representing a second data symbol.

2. The method of transmitting data of claim **1**, wherein the first data symbol represents a first group of binary digits, and the second data symbol represents a second group of binary digits.

3. The method of transmitting data of claim **1**, wherein the first and second data symbols each represent a multiplicity of binary digits.

4. The method of transmitting data of claim **1**, wherein the first and second data symbols each represent a group of binary digits selected from the group consisting of: 3 binary digits, 4 binary digits, 8 binary digits, 16 binary digits, 32 binary digits, 64 binary digits, 128 binary digits, 256 binary digits, 512 binary digits, and 1024 binary digits.

5. The method of transmitting data of claim **1**, wherein the ultra-wideband pulse comprises an impulse radio signal.

6. The method of transmitting data of claim **1**, wherein the ultra-wideband pulse comprises a burst of electromagnetic energy having a duration that ranges between about 0.1 nanoseconds to about 100 nanoseconds.

7. The method of transmitting data of claim **1**, wherein the ultra-wideband pulse comprises a burst of electromagnetic energy having a duration that can range between about 0.1 nanoseconds to about 100 nanoseconds and a power that ranges between about +30 power decibels to about −90 power decibels, as measured at a single frequency.

8. The method of transmitting data of claim **1**, wherein the wire medium is selected from a group consisting of: an optical fiber ribbon, a fiber optic cable, a single mode fiber optic cable, a multi-mode fiber optic cable, a twisted pair wire, an unshielded twisted pair wire, a plenum wire, a PVC wire, a coaxial cable, and an electrically conductive material.

9. The method of transmitting data of claim **1**, wherein the wire medium is part of a wire network that is selected from a group consisting of: a power line, an optical network, a cable television network, a community antenna television network, a community access television network, a hybrid fiber coax system network, a public switched telephone network, a wide area network, a local area network, a metropolitan area network, a TCP/IP network, a dial-up network, a switched network, a dedicated network, a non-switched network, a public network and a private network.

10. The method of transmitting data of claim **1**, wherein the ultra-wideband pulse is used to transmit data selected from a group consisting of: telephony data, high-speed data, digital video data, digital television data, Internet communication data and audio data.

11. A method of transmitting data through a wire medium, comprising the steps of:

means for providing the wire medium;

means for generating an ultra-wideband pulse, the ultra-wideband pulse including a first section representing a first data symbol, and a second section representing a second data symbol.

12. A method of transmitting data through a wire medium, comprising the steps of:

providing the wire medium; and

generating an ultra-wideband pulse, the ultra-wideband pulse comprising a plurality of time bins, with each time bin comprising a data symbol.

13. The method of transmitting data of claim **12**, wherein the data symbol represents a multiplicity of binary digits.

14. The method of transmitting data of claim **12**, wherein the data symbol represents a group of binary digits selected from the group consisting of: 3 binary digits, 4 binary digits, 8 binary digits, 16 binary digits, 32 binary digits, 64 binary digits, 128 digits, 256 binary digits, 512 binary digits, and 1024 binary digits.

15. The method of transmitting data of claim **12**, wherein a number of time bins may range between 3 time bins and 1024 time bins.

16. The method of transmitting data of claim **12**, wherein the ultra-wideband pulse comprises an impulse radio signal.

17. The method of transmitting data of claim **12**, wherein the ultra-wideband pulse comprises a burst of electromagnetic energy having a duration that ranges between about 0.1 nanoseconds to about 100 nanoseconds.

18. The method of transmitting data of claim **12**, wherein the ultra-wideband pulse comprises a burst of electromagnetic energy having a duration that ranges between about 0.1 nanoseconds to about 100 nanoseconds and a power that ranges between about +30 power decibels to about −90 power decibels, as measured at a single frequency.

19. The method of transmitting data of claim **12**, wherein the wire medium is selected from a group consisting of: an

optical fiber ribbon, a fiber optic cable, a single mode fiber optic cable, a multi-mode fiber optic cable, a twisted pair wire, an unshielded twisted pair wire, a plenum wire, a PVC wire, a coaxial cable, and an electrically conductive material.

20. The method of transmitting data of claim **12**, wherein the wire medium is part of a wire network that is selected from a group consisting of: a power line, an optical network, a cable television network, a community antenna television network, a community access television network, a hybrid fiber coax system network, a public switched telephone network, a wide area network, a local area network, a metropolitan area network, a TCP/IP network, a dial-up network, a switched network, a dedicated network, a non-switched network, a public network and a private network.

21. The method of transmitting data of claim **12**, wherein the ultra-wideband pulse is used to transmit data selected from a group consisting of: telephony data, high-speed data, digital video data, digital television data, Internet communication data and audio data.

22. A method of transmitting data through a wire medium, comprising the steps of:

providing the wire medium;

generating an ultra-wideband pulse, the ultra-wideband pulse comprising:

an amplitude that represents a first data symbol; and

a plurality of time bins, with each time bin representing a second data symbol.

23. The method of transmitting data of claim **22**, wherein the first and second data symbols each represent a multiplicity of binary digits.

24. The method of transmitting data of claim **22**, wherein the first and second data symbols each represent a group of binary digits selected from the group consisting of: 3 binary digits, 4 binary digits, 8 binary digits, 16 binary digits, 32 binary digits, 64 binary digits, 128 binary digits, 256 binary digits, 512 binary digits, and 1024 binary digits.

25. The method of transmitting data of claim **22**, wherein a number of time bins ranges between 3 time bins and 1024 time bins.

26. The method of transmitting data of claim **22**, wherein a number of amplitudes ranges between 3 amplitudes and 1024 amplitudes, with each amplitude representing a discrete data symbol.

27. The method of transmitting data of claim **22**, wherein the ultra-wideband pulse comprises an impulse radio signal.

28. The method of transmitting data of claim **22**, wherein the ultra-wideband pulse comprises a burst of electromagnetic energy having a duration that ranges between about 0.1 nanoseconds to about 100 nanoseconds.

29. The method of transmitting data of claim **22**, wherein the ultra-wideband pulse comprises a burst of electromagnetic energy having a duration that ranges between about 0.1 nanoseconds to about 100 nanoseconds and a power that ranges between about +30 power decibels to about −90 power decibels, as measured at a single frequency.

30. The method of transmitting data of claim **22**, wherein the wire medium is selected from a group consisting of: an optical fiber ribbon, a fiber optic cable, a single mode fiber optic cable, a multi-mode fiber optic cable, a twisted pair wire, an unshielded twisted pair wire, a plenum wire, a PVC wire, a coaxial cable, and an electrically conductive material.

31. The method of transmitting data of claim **22**, wherein the wire medium is part of a wire network that is selected from a group consisting of: a power line, an optical network, a cable television network, a community antenna television network, a community access television network, a hybrid fiber coax system network, a public switched telephone network, a wide area network, a local area network, a metropolitan area network, a TCP/IP network, a dial-up network, a switched network, a dedicated network, a non-switched network, a public network and a private network.

32. The method of transmitting data of claim **22**, wherein the ultra-wideband pulse is used to transmit data selected from a group consisting of: telephony data, high-speed data, digital video data, digital television data, Internet communication data and audio data.

* * * * *

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(12) **United States Patent**
Santhoff et al.

(10) **Patent No.: US 7,099,368 B2**
(45) **Date of Patent: Aug. 29, 2006**

(54) **ULTRA-WIDEBAND COMMUNICATION THROUGH A WIRE MEDIUM**

(75) Inventors: **John Santhoff**, Carlsbad, CA (US); **Steve Moore**, Escondido, CA (US)

(73) Assignee: **Pulse-LINK, Inc.**, Carlsbad, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 50 days.

(21) Appl. No.: **10/855,172**

(22) Filed: **May 26, 2004**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H04B 1/69 (2006.01)

(52) **U.S. Cl.** **375/130**

(58) **Field of Classification Search** 375/130, 375/256, 257, 259, 260; 342/202
See application file for complete search history.

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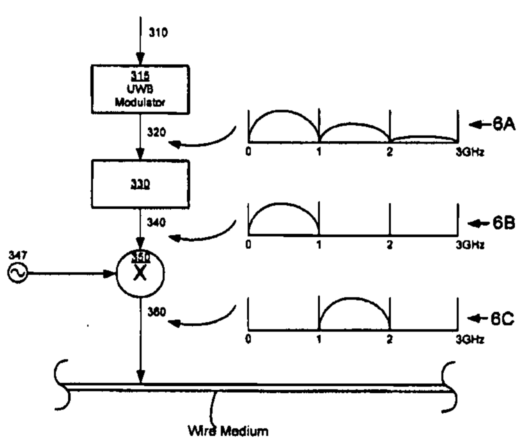
Primary Examiner—Don N. Vo
(74) *Attorney, Agent, or Firm*—Pulse-LINK, Inc.; Peter R Martinez

(57) **ABSTRACT**

Methods and apparatus for creating, transmitting and receiving ultra-wideband pulses through wire media are presented. One embodiment of the present invention transmits ultra-wideband pulses that occupy radio frequencies that are not used by other electromagnetic signals present in a wire medium of interest. Other embodiments of the invention may create, transmit, and receive ultra-wideband pulses that use radio frequency(s) that are not used by other signals present on wire media within a wire network of interest. This Abstract is provided for the sole purpose of complying with the Abstract requirement rules that allow a reader to quickly ascertain the subject matter of the disclosure contained herein. This Abstract is submitted with the explicit understanding that it will not be used to interpret or to limit the scope or the meaning of the claims.

36 Claims, 12 Drawing Sheets



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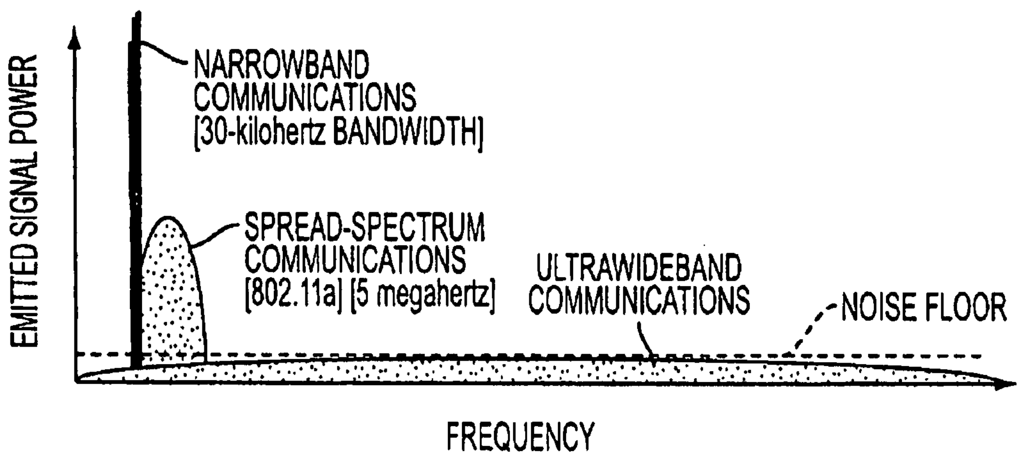

EMITTED SIGNAL POWER
NARROWBAND COMMUNICATIONS [30-kilohertz BANDWIDTH]
SPREAD-SPECTRUM COMMUNICATIONS [802.11a] [5 megahertz]
ULTRAWIDEBAND COMMUNICATIONS
NOISE FLOOR
FREQUENCY

FIG. 1

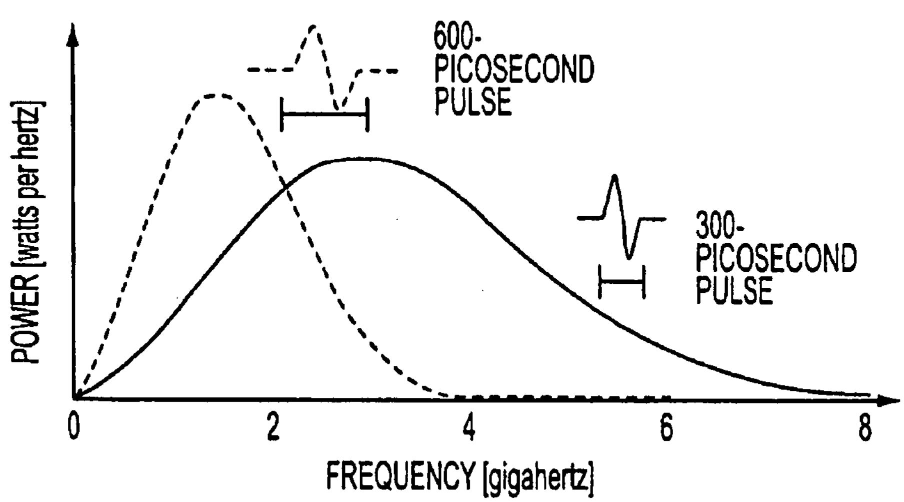

POWER [watts per hertz]
600-PICOSECOND PULSE
300-PICOSECOND PULSE
0
2
4
6
8
FREQUENCY [gigahertz]

FIG. 2

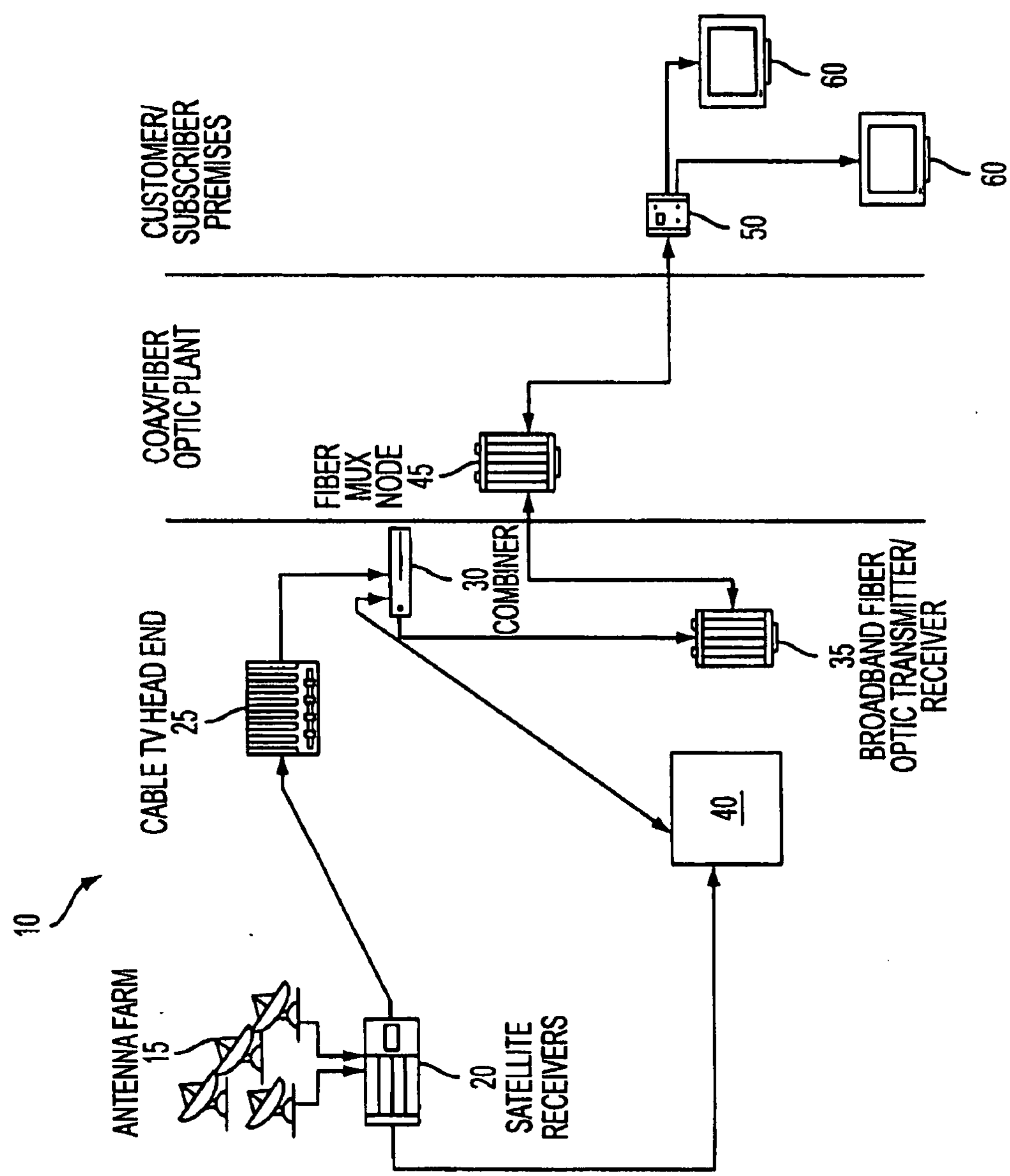

CUSTOMER/ SUBSCRIBER PREMISES
COAX/FIBER OPTIC PLANT
CABLE TV HEAD END 25
ANTENNA FARM 15
10
20 SATELLITE RECEIVERS
30 COMBINER
FIBER MUX NODE 45
35 BROADBAND FIBER OPTIC TRANSMITTER/ RECEIVER
40
50
60
60

FIG. 3

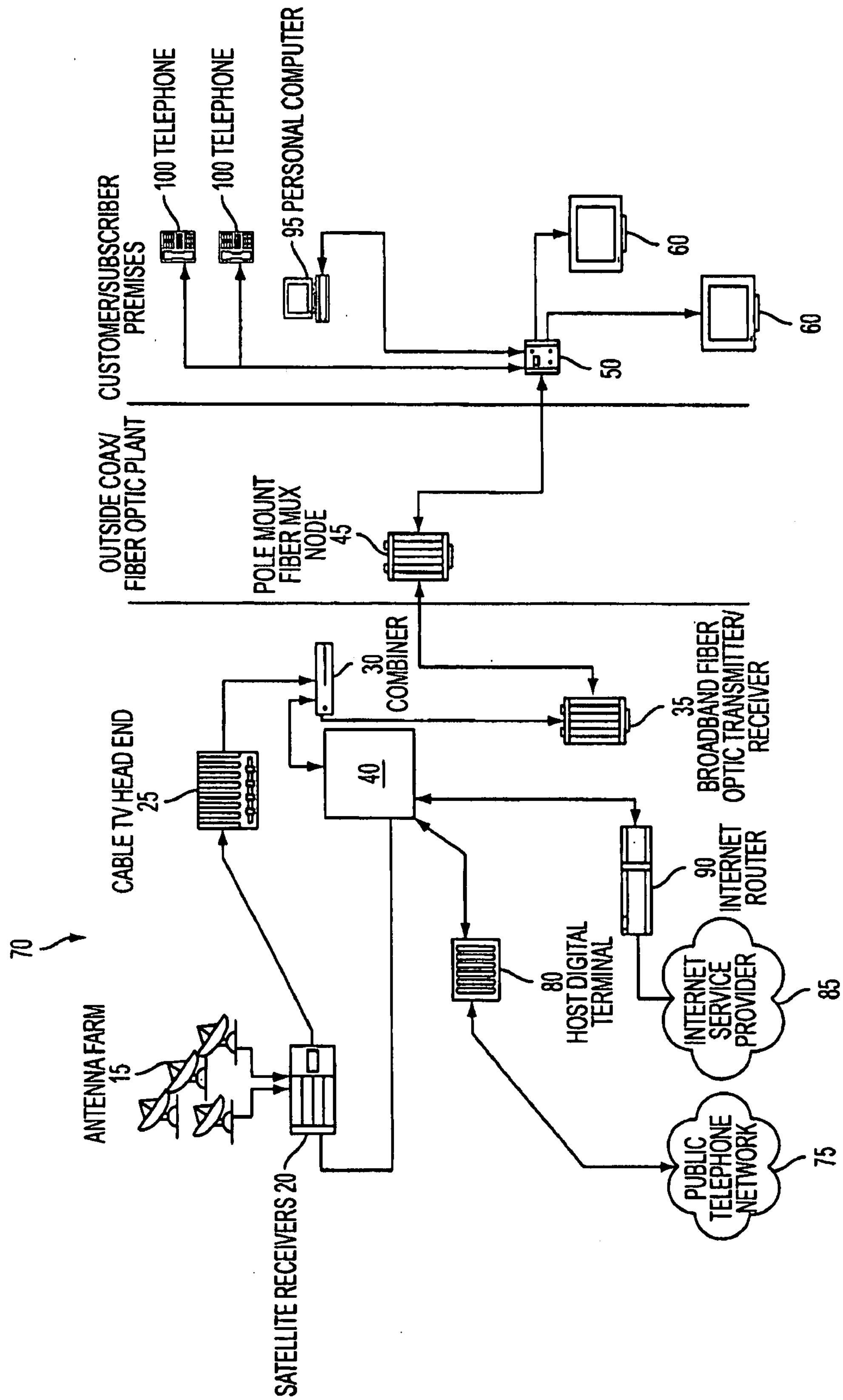

70
ANTENNA FARM 15
SATELLITE RECEIVERS 20
CABLE TV HEAD END 25
30 COMBINER
40
35 BROADBAND FIBER OPTIC TRANSMITTER/ RECEIVER
80 HOST DIGITAL TERMINAL
90 INTERNET ROUTER
INTERNET SERVICE PROVIDER
85
PUBLIC TELEPHONE NETWORK
75
OUTSIDE COAX/ FIBER OPTIC PLANT
POLE MOUNT FIBER MUX NODE 45
CUSTOMER/SUBSCRIBER PREMISES
100 TELEPHONE
100 TELEPHONE
95 PERSONAL COMPUTER
50
60
60

FIG. 4

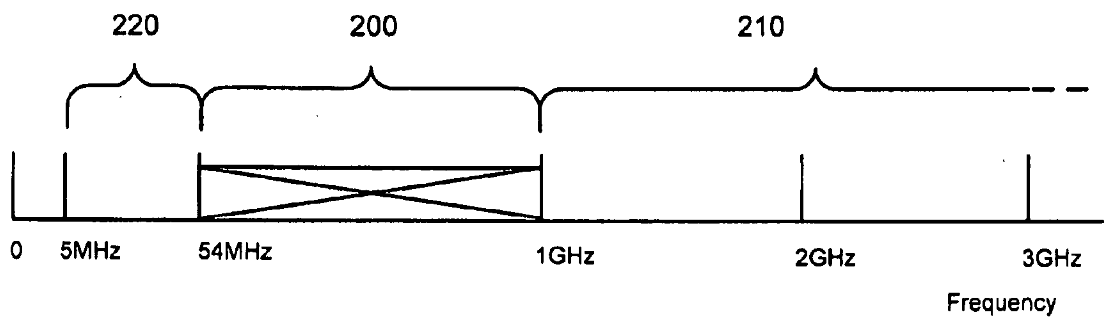
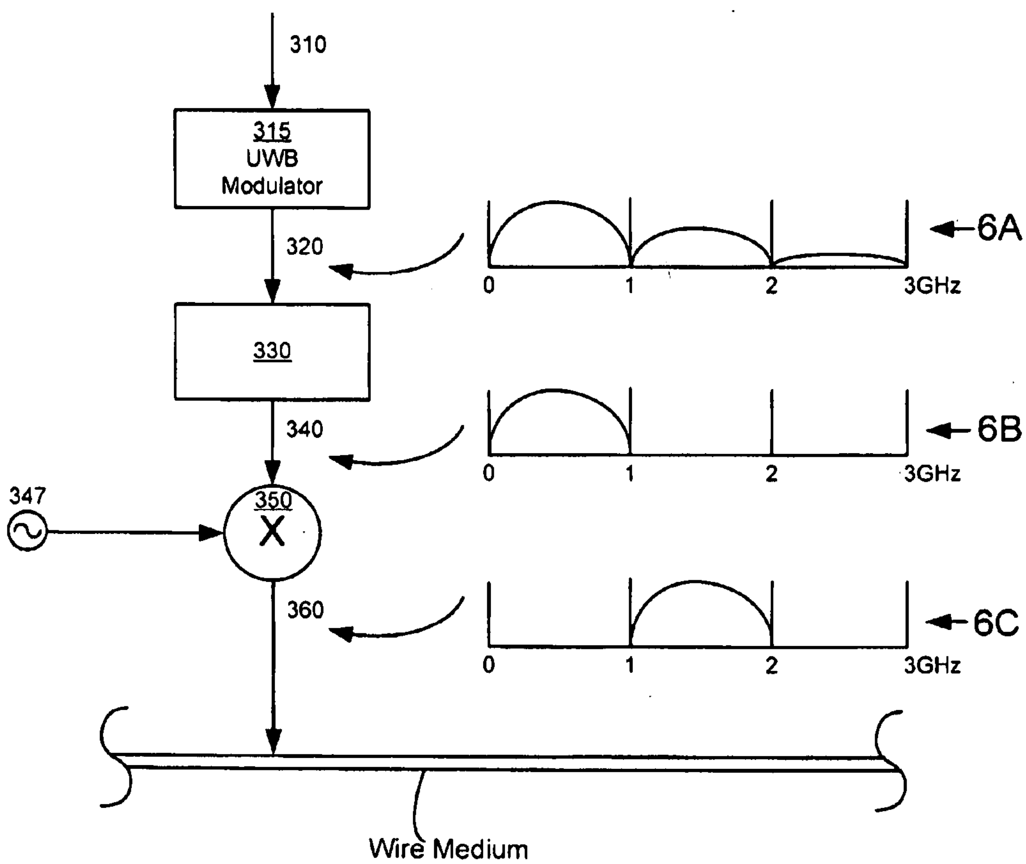


FIG. 5



310
315
UWB
Modulator
320
330
340
347
350
X
360
0
1
2
3GHz
6A
6B
6C
Wire Medium

FIG. 6

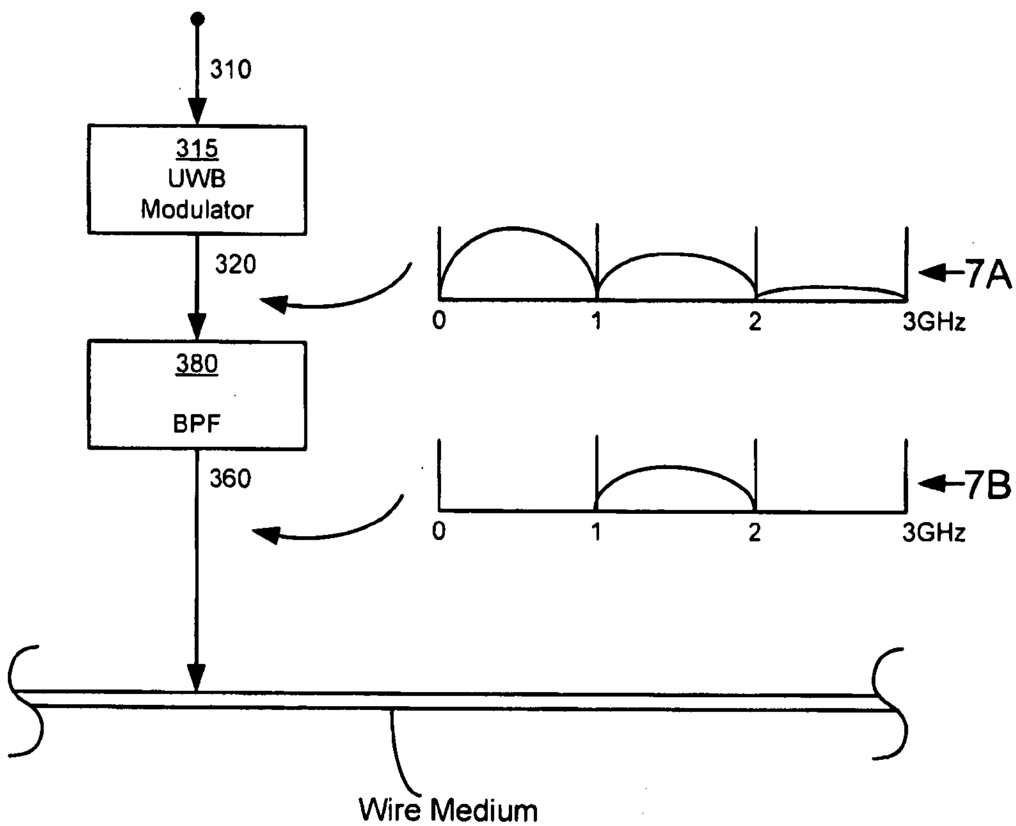
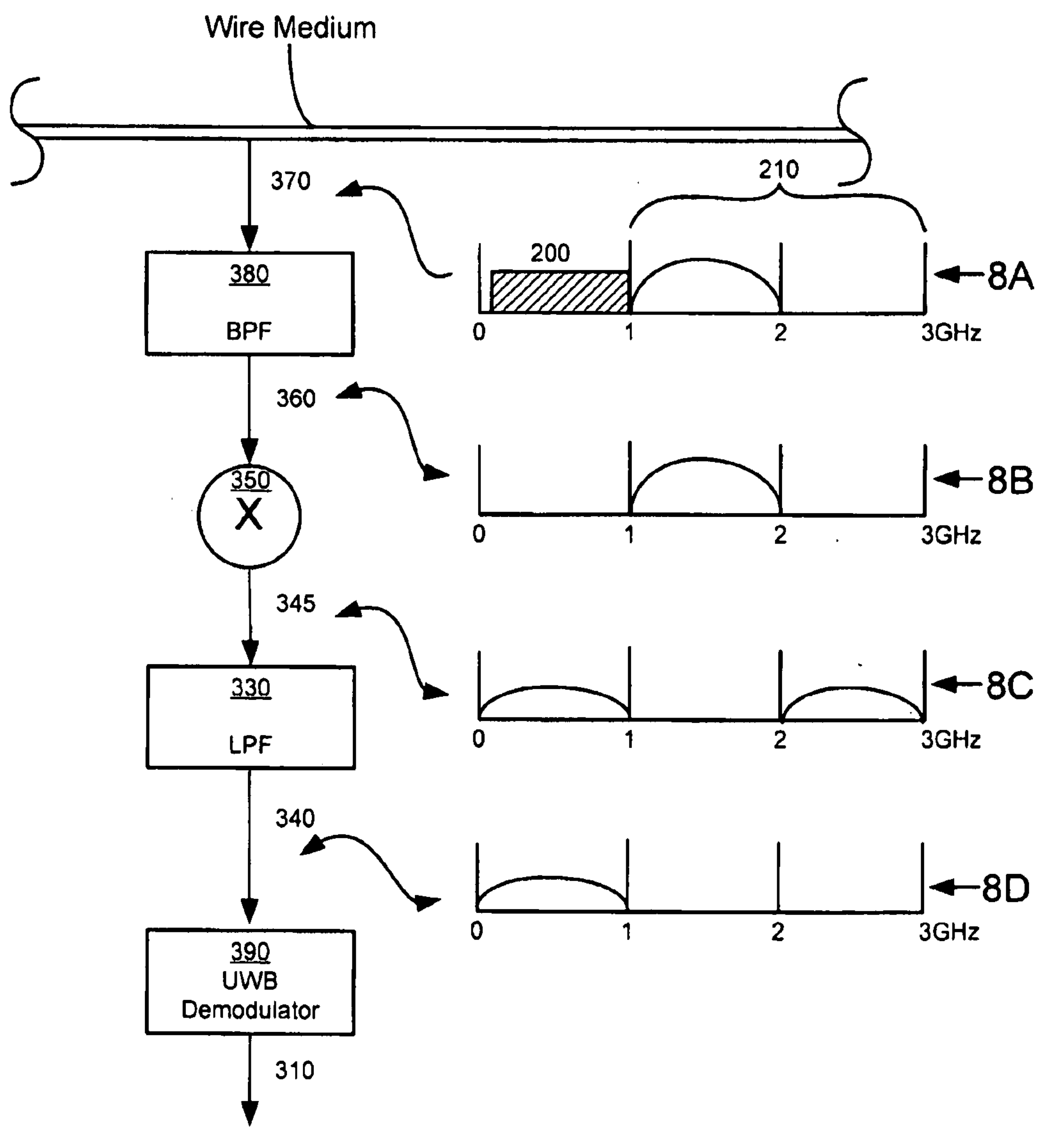
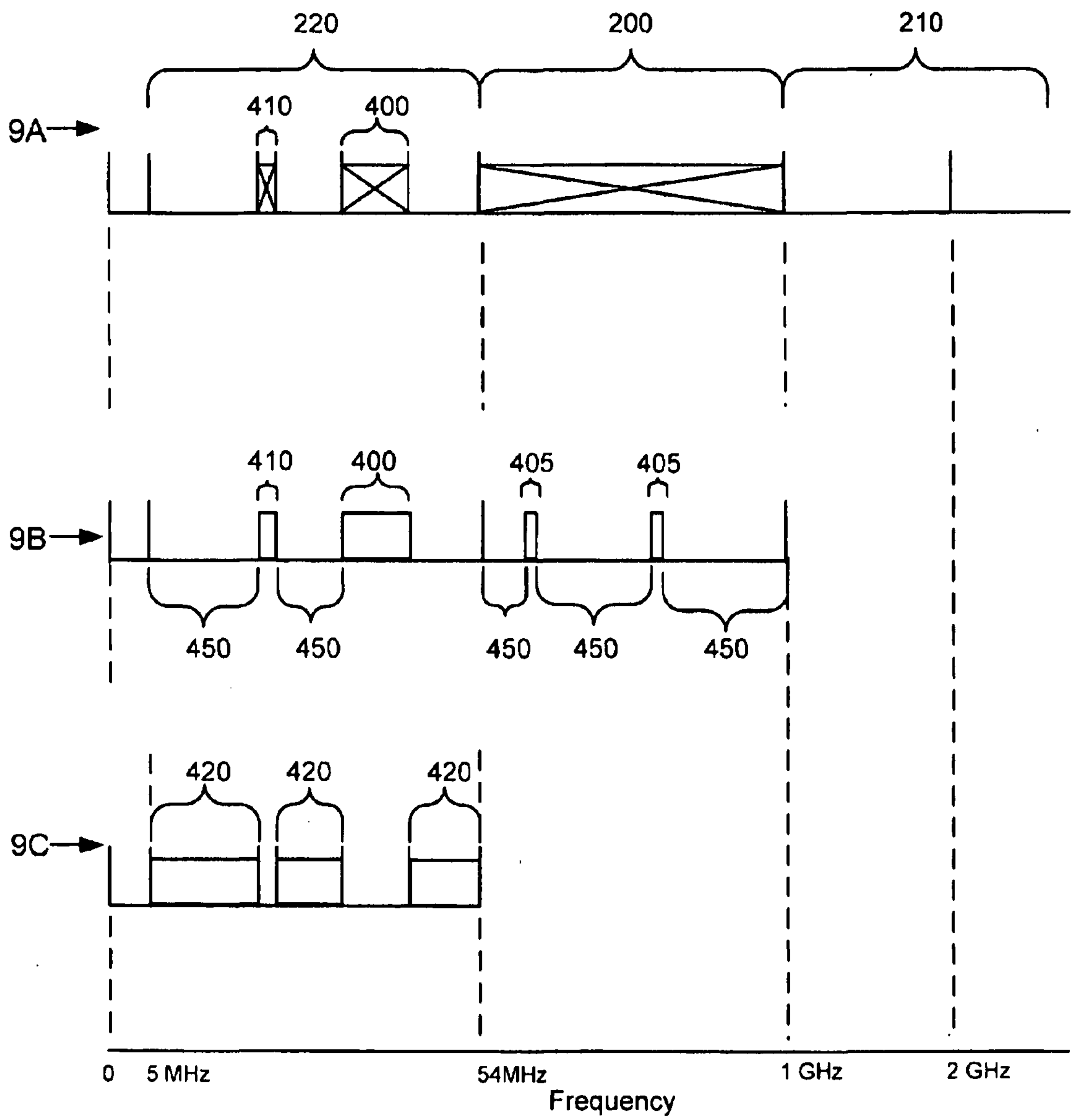

310
315
UWB
Modulator
320
380
BPF
360
0
1
2
3GHz
7A
0
1
2
3GHz
7B
Wire Medium

FIG. 7



Wire Medium
370
210
200
380
BPF
8A
0
1
2
3GHz
360
350
X
8B
345
330
LPF
8C
340
8D
390
UWB
Demodulator
310

FIG. 8



220
200
210
9A
410
400
9B
410
400
405
405
450
450
450
450
450
9C
420
420
420
0
5 MHz
54MHz
1 GHz
2 GHz
Frequency

FIGS. 9A - 9C

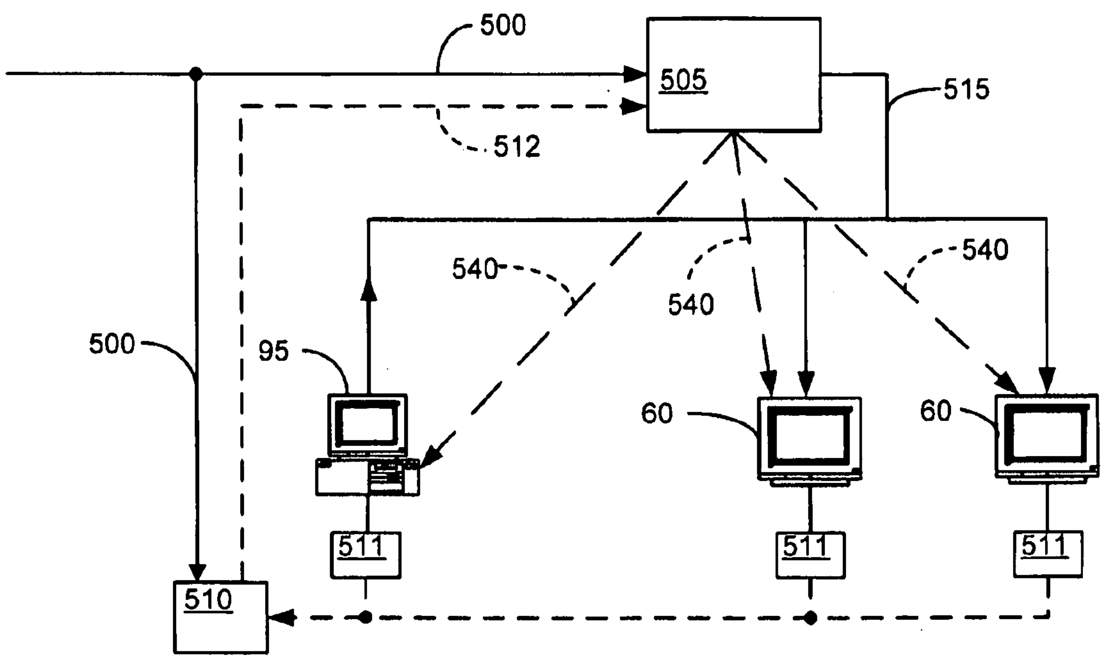


FIG. 10

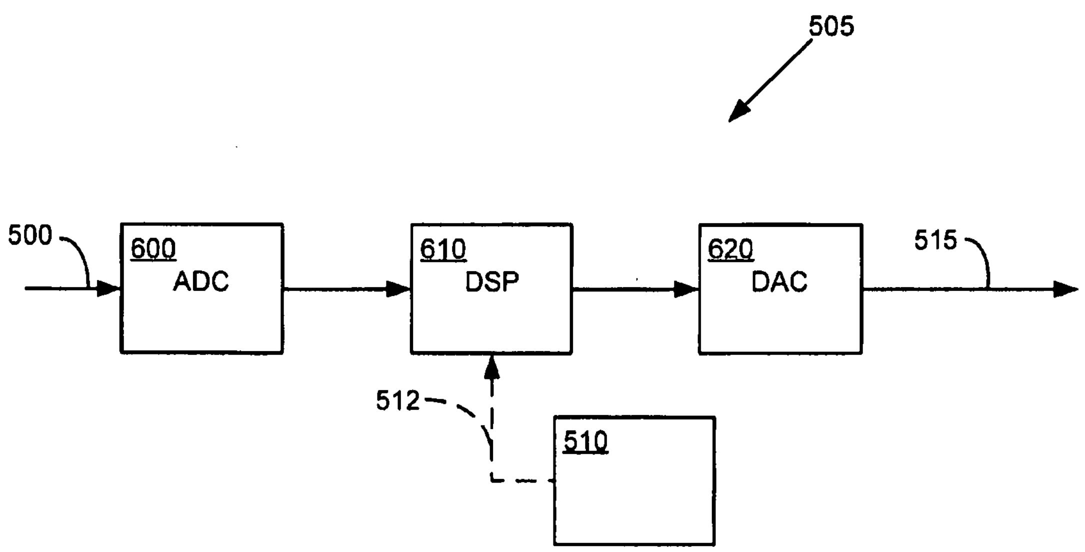


FIG. 11

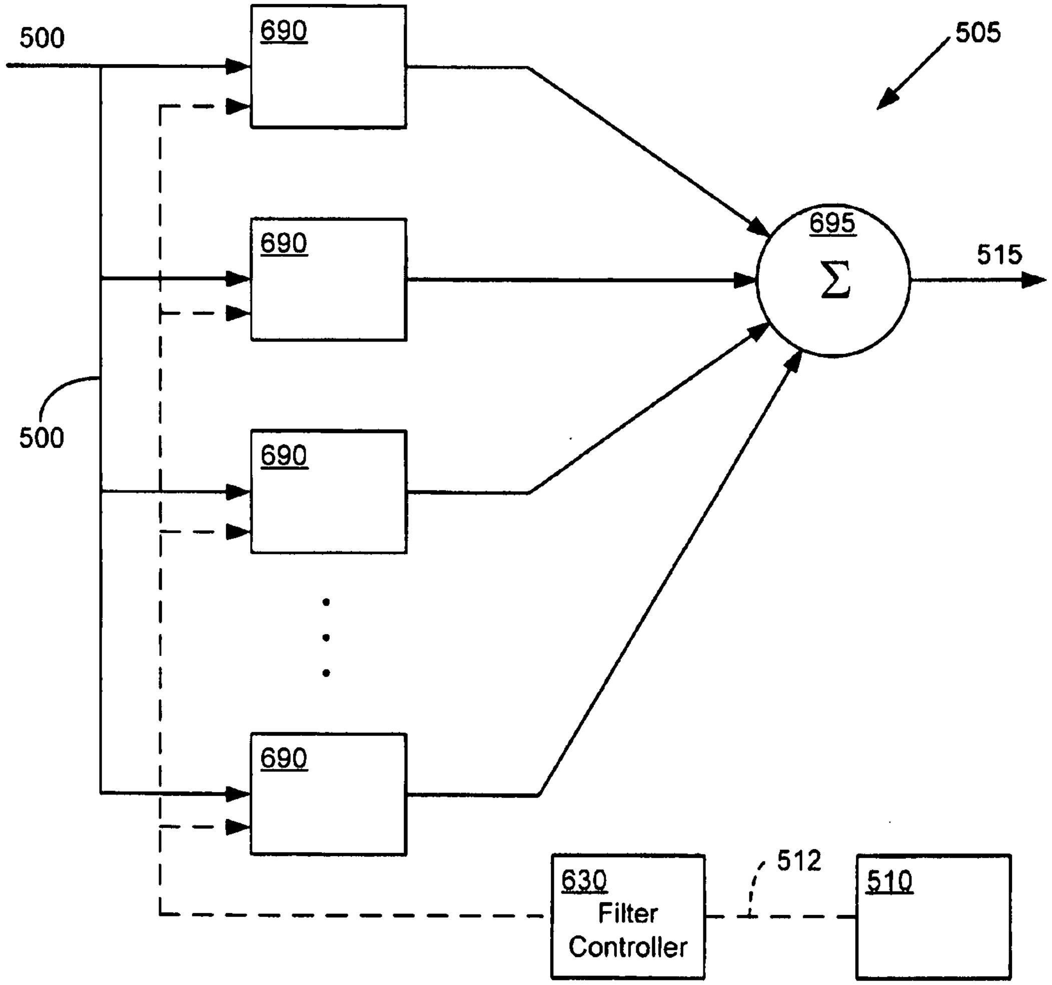

500
690
505
690
695
Σ
515
500
690
690
630
Filter
Controller
512
510

FIG. 12

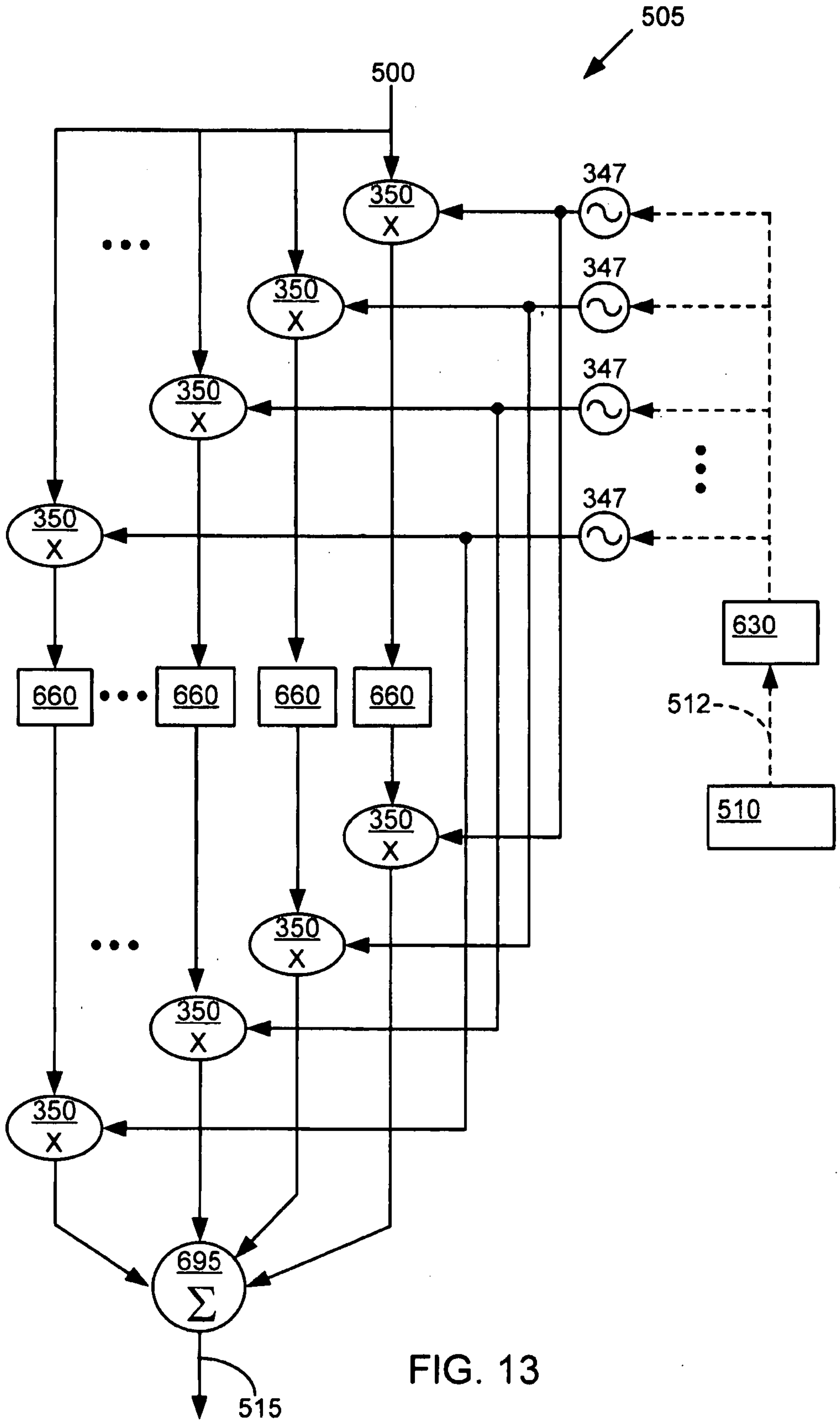

505
500
347
347
347
347
350
X
350
X
350
X
350
X
660
660
660
660
630
512
510
350
X
350
X
350
X
350
X
695
Σ
515

FIG. 13

ULTRA-WIDEBAND COMMUNICATION THROUGH A WIRE MEDIUM

This is a continuation-in-part of co-pending U.S. patent application Ser. No. 10/177,313, filed Jun. 21, 2002, entitled: ULTRA-WIDEBAND COMMUNICATION THROUGH A WIRED MEDIUM.

FIELD OF THE INVENTION

The present invention generally relates to UWB communications. More particularly, the invention concerns a method to transmit UWB signals over a wire medium.

BACKGROUND OF THE INVENTION

The Information Age is upon us. Access to vast quantities of information through a variety of different communication systems are changing the way people work, entertain themselves, and communicate with each other. For example, as a result of increased telecommunications competition mapped out by Congress in the 1996 Telecommunications Reform Act, traditional cable television program providers have evolved into full-service providers of advanced video, voice and data services for homes and businesses. A number of competing cable companies now offer cable systems that deliver all of the just-described services via a single broadband network.

These services have increased the need for bandwidth, which is the amount of data transmitted or received per unit time. More bandwidth has become increasingly important, as the size of data transmissions has continually grown. Applications such as in-home movies-on-demand and video teleconferencing demand high data transmission rates. Another example is interactive video in homes and offices.

Other industries are also placing bandwidth demands on Internet service providers, and other data providers. For example, hospitals transmit images of X-rays and CAT scans to remotely located physicians. Such transmissions require significant bandwidth to transmit the large data files in a reasonable amount of time. These large data files, as well as the large data files that provide real-time home video are simply too large to be feasibly transmitted without an increase in system bandwidth. The need for more bandwidth is evidenced by user complaints of slow Internet access and dropped data links that are symptomatic of network overload.

Internet service providers, cable television networks and other data providers generally employ conductive wires and cables to transmit and receive data. Conventional approaches to signal (i.e. data) transmission through a transmission medium, such as a wire or cable, is to modulate the signal though the medium at a frequency that lies within the bounds at which the medium can electrically conduct the signal. Because of this conventional approach, the bandwidth of a specific medium is limited to a spectrum within which the medium is able to electrically transmit the signal via modulation, which yields a current flow. As a result, many costly and complicated schemes have been developed to increase the bandwidth in conventional conductive wire and/or cable systems using sophisticated switching schemes or signal time-sharing arrangements. Each of these methods is rendered costly and complex in part because the data transmission systems adhere to the conventional acceptance that the bandwidth of a wire or cable is constrained by its conductive properties.

Therefore, there exists a need for a method to increase the bandwidth of conventional wire networks.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus to transmit ultra-wideband pulses through wire media. One embodiment of the present invention transmits ultra-wideband pulses that occupy radio frequencies that are not used by other electromagnetic signals present in a wire medium of interest.

In another embodiment of the invention, a plurality of ultra-wideband pulses are created, transmitted, and received using radio frequency(s) that are not used by cable television signals. Other embodiments of the invention may create, transmit, and receive ultra-wideband pulses that use radio frequency(s) that are not used by signals present on wire media within any wire network of interest.

One feature of the present invention is that ultra-wideband pulses can be transmitted substantially simultaneously with a traditional cable television signal, Internet connection signal or voice transmission signal. Because the ultra-wideband signal can be transmitted substantially simultaneously with the other signals, the overall bandwidth or capability of the system to transmit data is vastly increased.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of different communication methods;

FIG. **2** is an illustration of two ultra-wideband pulses;

FIG. **3** is a schematic illustration of one embodiment of an ultra-wideband communication system employing a wired medium;

FIG. **4** is a schematic illustration of a second embodiment of an ultra-wideband communication system employing a wired medium;

FIG. **5** is an illustration of a portion of the radio frequency spectrum;

FIG. **6** illustrates a first method of the invention that introduces ultra-wideband pulses into a wire medium;

FIG. **7** illustrates a second method of the invention that introduces ultra-wideband pulses into a wire medium;

FIG. **8** illustrates a method of the invention that obtains ultra-wideband pulses from a wire medium;

FIGS. **9**A–C illustrates a portion of the radio frequency spectrum including examples of several radio frequency bands that may be used by one embodiment of the present invention;

FIG. **10** illustrates one example of the customer/subscriber premises shown in FIGS. **3** and **4**, including a dynamic filter constructed according to one embodiment of the present invention;

FIG. **11** illustrates one embodiment of the dynamic filter shown in FIG. **10**;

FIG. **12** illustrates a second embodiment of the dynamic filter shown in FIG. **10**; and

FIG. **13** illustrates a third embodiment of the dynamic filter shown in FIG. **10**.

It will be recognized that some or all of the Figures are schematic representations for purposes of illustration and do not necessarily depict the actual relative sizes or locations of the elements shown. The Figures are provided for the purpose of illustrating one or more embodiments of the invention with the explicit understanding that they will not be used to limit the scope or the meaning of the claims.

DETAILED DESCRIPTION OF THE INVENTION

In the following paragraphs, the present invention will be described in detail by way of example with reference to the attached drawings. Throughout this description, the preferred embodiment and examples shown should be considered as exemplars, rather than as limitations on the present invention. As used herein, the "present invention" refers to any one of the embodiments of the invention described herein, and any equivalents. Furthermore, reference to various feature(s) of the "present invention" throughout this document does not mean that all claimed embodiments or methods must include the referenced feature(s).

Generally, a traditional cable television provider, a community antenna television provider, a community access television provider, a cable television provider, a hybrid fiber-coax television provider, an Internet service provider, or any other provider of television, audio, voice and/or Internet data receives broadcast signals at a central station, either from terrestrial cables, and/or from one or more antennas that receive signals from a communications satellite. The broadcast signals are then distributed, usually by coaxial and/or fiber optic cable, from the central station to nodes located in business or residential areas.

For example, community access television provider (CATV) networks are currently deployed in several different topologies and configurations. The most common configurations found today are analog signals transmitted over coaxial cable and Hybrid Fiber-Coax Systems (HFCS) that employ both fiber optic and coaxial cables. The analog coax systems are typically characterized as pure analog systems. Pure analog CATV systems are characterized by their use of established NTSC/PAL (National Television Standards Committee/Phase Alternation Line) modulation onto a frequency carrier at 6 or 8 MHz intervals.

HFCS is a combination analog—digital topology employing both coaxial (analog) and fiber optic (digital) media that typically supports digitally modulated/encoded television channels above channel **78**. According to ANSI/EIA-542-1997, in the United States, the analog channels are modulated in 6 MHz allocations on channels **2** to **78** using frequencies from 55 to 547 MHz. When using HFCS, digital channels typically start at channel **79** and go as high as **136** and occupy a frequency range from 553 to 865 MHz. In some extended HFCS systems, channel assignments can go as high as channel **158** or 997 MHz. The current ANSI/EIA-542-1997 standard only defines and assigns channels to these limits. The actual wire/cable media itself is generally capable of transmitting frequencies up to 3 GHz.

In both CATV and HFCS systems, typically the satellite downlink enters the cable company's head-end and the video, and/or other data streams are de-multiplexed out. Individual video data streams (either NTSC, MPEG, or any other suitable protocol) are extracted from the satellite downlink stream and routed to modulators specific for individual television channels. The outputs from each modulator are then combined into one broadband signal. From this point the combined channels are amplified and sent out, either by coaxial or fiber optic cable, to the customers.

In a HFCS, before the combined broadband signal leaves the head-end the broadband signal is modulated onto a fiber optic cable for distribution into the field, such as residential neighborhoods, or business districts. Modulation of the broadband signal is typically accomplished in one of two ways. In the first method the entire broadband signal is sampled and digitized using a high speed Analog to Digital Converter (ADC). To perform reliable digital sampling, the data must be sampled at a rate at least twice the highest frequency component to meet Nyquist minimum sampling requirements. To provide a higher quality data stream, the signal should be sampled at 2.5 to 4 times the highest frequency, which entails sample rates of approximately 2 to 4 GHz. A parallel to serial converter then shifts the parallel output data of the ADC into a serial format. The serial data then drives a laser diode for transmission over the fiber optic cable. The second method is broadband block conversion where the entire spectrum of the broadband signal is modulated onto the fiber optic cable.

Designated access nodes are located in neighborhoods, business districts and other areas. The access nodes contain a high speed Digital to Analog Converter (DAC) and a de-serializer. A fiber optic receiver detects the laser-modulated signal at the access node. A parallel to serial converter de-serializes the data and it is feed to the high speed DAC. The data then leaves the access node on standard 75 ohm, RG-6 or RG-8 or other suitable coax cable and is distributed to the customer's premises. Thus, at the access node, the broadband signal is extracted from the fiber optic cable and transferred to a coaxial cable that connects to individual homes, apartments, businesses, universities, and other customers. Support of multiple customers is generally accomplished by the use of distribution boxes in the field, for example, on telephone poles or at ground level. However, as the signal is continuously split at the distribution boxes, the received bandwidth is reduced and the quality of the signal is diminished, thereby diminishing the video, audio, and other data quality.

The digital channels that generally reside on CATV channels **79** and higher are fundamentally different than the analog channels that generally reside on channels **2** through **78**. The analog channels are composed of modulated frequency carriers. The digital channels, which generally use the 6 MHz allocation system, are digitally modulated using Quadrature Amplitude Modulation (QAM). QAM is a method of combining two amplitude-modulated signals into a single channel, thereby doubling the effective bandwidth. In a QAM signal, there are two carriers, each having the same frequency but differing in phase by 90 degrees. The two modulated carriers are combined for transmission, and separated after transmission. QAM **16** transmits 16 bits per signal, QAM **32**, **64**, and **256** each transmit 32, 54 and 256 bits per signal, respectively. QAM was developed to support additional video streams encoded with MPEG video compression. Conventional CATV and HFCS networks may employ QAM levels up to QAM **64** to enable up to 8 independent, substantially simultaneous MPEG video streams to be transmitted.

At the customer's location, the coaxial cable is connected to either a set-top box or directly to a television. The receiving device then de-multiplexes and de-modulates the video, audio, voice, Internet or other data. Although a television can directly receive the analog signal, a set-top box is generally required for reception of the digitally encoded channels residing on CATV channels **79** and higher.

The above-described networks, and other networks and communication systems that employ wired media, such as twisted-pair or coaxial cable, suffer from performance limitations caused by signal interference, ambient noise, and spurious noise. In these conventional wired media systems, these limitations affect the available system bandwidth, distance, and carrying capacity of the system, because the noise floor and signal interference in the wired media rapidly overcome the signal transmitted. Therefore, noise within the

wired media significantly limits the available bandwidth of any wired system or network.

Generally, the conventional wisdom for overcoming this limitation is to boost the power (i.e., increase the voltage of the signal) at the transmitter to boost the voltage level of the signal relative to the noise at the receiver. Without boosting the power at the transmitter, the receiver is unable to separate the noise from the desired signal. Thus, the overall performance of wired media systems is still significantly limited by the accompanying noise that is inherent in wired media.

Increasing the available bandwidth of an established wired media network, while coexisting with the conventional data signals transmitted through the network, represents an opportunity to leverage the existing wired media network infrastructure to enable the delivery of greater functionality. Several methods and techniques have been proposed, but they are generally computationally intense, hence costly.

The present invention may be employed in any type of network that uses wired media, in whole, or in part. That is, a network may use both wired media, such as coaxial cable, and wireless devices, such as satellites. As defined herein, a network is a group of points or nodes connected by communication paths. The communication paths may be connected by wires, or they may be wirelessly connected. A network as defined herein can interconnect with other networks and contain subnetworks. A network as defined herein can be characterized in terms of a spatial distance, for example, such as a local area network (LAN), a metropolitan area network (MAN), and a wide area network (WAN), among others. A network as defined herein can also be characterized by the type of data transmission technology in use on it, for example, a TCP/IP network, and a Systems Network Architecture network, among others. A network as defined herein can also be characterized by whether it carries voice, data, or both kinds of signals. A network as defined herein can also be characterized by who can use the network, for example, a public switched telephone network (PSTN), other types of public networks, and a private network (such as within a single room or home), among others. A network as defined herein can also be characterized by the usual nature of its connections, for example, a dial-up network, a switched network, a dedicated network, and a nonswitched network, among others. A network as defined herein can also be characterized by the types of physical links that it employs, for example, optical fiber, coaxial cable, a mix of both, unshielded twisted pair, and shielded twisted pair, among others.

The present invention employs a substantially "carrier free" architecture which does not require the use of noise waveform detectors, stabilizers, or other devices employed in conventional frequency domain communication systems. The present invention dramatically increases the bandwidth of conventional networks that employ wired media, but can be inexpensively deployed without extensive modification to the existing wired media network.

The present invention provides increased bandwidth by injecting, or otherwise super-imposing an ultra-wideband (UWB) signal into the existing data signal and subsequently recovers the UWB signal at an end node, set-top box, subscriber gateway, or other suitable location. Ultra-wideband, or impulse radio, employs pulses of electromagnetic energy that are emitted at nanosecond or picosecond intervals (generally tens of picoseconds to a few nanoseconds in duration). For this reason, ultra-wideband is often called "impulse radio." Because the excitation pulse is not a modulated waveform, UWB has also been termed "carrier-free" in that no apparent carrier frequency is evident in the radio frequency (RF) spectrum. That is, the UWB pulses are transmitted without modulation onto a sine wave carrier frequency, in contrast with conventional radio frequency technology. Ultra-wideband requires neither an assigned frequency nor a power amplifier.

Conventional radio frequency technology employs continuous sine waves that are transmitted with data embedded in the modulation of the sine waves' amplitude or frequency. For example, a conventional cellular phone must operate at a particular frequency band of a particular width in the total frequency spectrum. Specifically, in the United States, the Federal Communications Commission has allocated cellular phone communications in the 800 to 900 MHz band. Cellular phone operators use 25 MHz of the allocated band to transmit cellular phone signals, and another 25 MHz of the allocated band to receive cellular phone signals.

Another example of a conventional radio frequency technology is illustrated in FIG. **1**. 802.11a, a wireless local area network (LAN) protocol, transmits radio frequency signals at a 5 GHz center frequency, with a radio frequency spread of about 5 MHz.

In contrast, a UWB pulse may have a 1.8 GHz center frequency, with a frequency spread of approximately 4 GHz, as shown in FIG. **2**, which illustrates two typical UWB pulses. FIG. **2** illustrates that the narrower the UWB pulse in time, the higher its center frequency and the broader the spread of its frequency spectrum. This is because frequency is inversely proportional to the time duration of the pulse. A 600 picosecond UWB pulse will have about a 1.8 GHz center frequency, with a frequency spread of approximately 4 GHz. And a 300 picosecond UWB pulse will have about a 3 GHz center frequency, with a frequency spread of approximately 8 GHz. Thus, UWB pulses generally do not operate within a specific frequency, as shown in FIG. **1**. And because UWB pulses are spread across an extremely wide frequency range, UWB communication systems allow communications at very high data rates, such as 100 megabits per second or greater.

Further details of UWB technology are disclosed in U.S. Pat. No. 3,728,632 (in the name of Gerald F. Ross, and titled: Transmission and Reception System for Generating and Receiving Base-Band Duration Pulse Signals without Distortion for Short Base-Band Pulse Communication System), which is referred to and incorporated herein in its entirety by this reference.

Also, because the UWB pulse is spread across an extremely wide frequency range, the power sampled at a single, or specific frequency is very low. For example, a UWB one-watt signal of one nano-second duration spreads the one-watt over the entire frequency occupied by the pulse. At any single frequency, such as at the carrier frequency of a CATV provider, the UWB pulse power present is one nano-watt (for a frequency band of 1 GHz). This is well within the noise floor of any wired media system and therefore does not interfere with the demodulation and recovery of the original CATV signals. Generally, the multiplicity of UWB pulses are transmitted at relatively low power (when sampled at a single, or specific frequency), for example, at less than −30 power decibels to −60 power decibels, which minimizes interference with conventional radio frequencies. However, UWB pulses transmitted through most wired media will not interfere with wireless radio frequency transmissions. Therefore, the power

(sampled at a single frequency) of UWB pulses transmitted though wired media may range from about +30 dB to about -90 dB.

For example, a CATV system generally employs a coaxial cable that transmits analog data on a frequency carrier. Generally, amplitude modulation (AM) or QAM (discussed above) are used to transmit the analog data. Since data transmission employs either AM or QAM, UWB signals can coexist in this environment without interference. In AM, the data signal M(t) is multiplied with a cosine at the carrier frequency. The resultant signal y(t) can be represented by:

$$y(t)=m(t)\mathrm{Cos}(\omega_c t)$$

In a QAM based system multiple carrier signals are transmitted at the same carrier frequency, but at different phases. This allows multiple data signals to be simultaneously carried. In the case of two carriers, an "in phase" and "quadrature" carriers can carry data signals Mc(t) and Ms(t). The resultant signal y(t) can be represented as:

$$y(t)=Mc(t)\mathrm{Cos}(\omega_c t)+Ms(t)\mathrm{Sin}(\omega_c t)$$

However, as discussed above, an UWB system transmits a narrow time domain pulse, and the signal power is generally evenly spread over the entire bandwidth occupied by the signal. At any instantaneous frequency, such as at the AM or QAM carrier frequency, the UWB pulse power present is one nano-watt (for a frequency band of 1 GHz). This is well within the noise floor of any wired media system and therefore does not interfere with the demodulation and recovery of the original AM or QAM data signals.

Wired media communication systems suffer from performance limitations caused by signal interference, ambient noise, and spurious noise. These limitations affect the available bandwidth, distance, and carrying capacity of the wire media system. With wired communication systems, the noise floor and signal interference in the wired media rapidly overcome the transmitted carrier signal. This noise on the wired media is a significant limitation to the ability of the system to increase bandwidth. UWB technology makes use of the noise floor to transmit data, without interfering with the carrier signal. Moreover, UWB transmitted through a wired medium has distinct advantages over its use in a wireless environment. In a wired environment there are no concerns with intersymbol interference, and there are no concerns relating to multi-user interference.

For example, CATV channels typically occupy 6 MHz in the US and 8 MHz in Europe. These channels are arranged in a re-occurring pattern beginning at approximately 50 MHz and dependent on the CATV system, extend upward to 550 MHz, 750 MHz, 870 MHz, 1 GHz and higher. The present invention is capable of injecting UWB pulses into the existing CATV infrastructure. These UWB signals do not interfere or degrade existing frequency domain signals. Additionally, the UWB signals can carry vast amounts of information with digital meaning in the time domain.

The present invention provides an apparatus and method to enable any wired media network to augment their available bandwidth. Preferably, this additional bandwidth is obtained by introducing UWB signals into the existing data transmission chain prior to broadcast from the system operator's head-end. As shown in FIGS. **3** and **4**, the head-end may include several components, such as the antenna farm **15**, the satellite receivers **20**, the channel modulator **25**, the combiner **30**, and the fiber optic transmitter/receiver **35**. Alternatively, UWB signals may be introduced into the wired media network at other locations, such as at the Internet router **90** or at the host digital terminal **80**, or at any other suitable location.

In like fashion, cable system operators can receive more data from individual subscribers by introducing subscriber-generated data into existing upstream channels. The present invention provides UWB communication across fiber optic and coaxial cable, twisted pair wires, or any other type of conductive wire. A wired media network will be able to both transmit and receive digital information for the purposes of telephony, high-speed data, video distribution, video conferencing, wireless base operations and other similar purposes.

Referring to FIG. **3**, the wired ultra-wideband communication system **10** is configured to transmit ultra-wideband signals over an existing network or system that includes wired media. For example, the wired ultra-wideband (UWB) system **10** may transmit UWB signals over an existing community access television network (CATV), an optical network, a cable television network, a community antenna television network, a hybrid fiber-coax television network, an Internet service provider network, a PSTN network, a WAN, LAN, MAN, TCP/IP network, a college campus, town, city, or any other type of network as defined above, that employs wired media, in whole or in part.

One embodiment of the wired UWB communication system **10** is illustrated in FIG. **3**. An antenna farm **15** receives audio, video and data information from one or more satellites (not shown). Additional data may be received by terrestrial cables and wires, and by terrestrial wireless sources, such as a multichannel multipoint distribution service (MMDS). The data is then forwarded to the satellite receivers **20** that demodulate the data into separate audio, video and data streams. This information is forwarded to the channel modulators **25** that receive the program signals, such as CNN or MTV. The channel modulators **25** mix each signal with a radio frequency (RF) and assign a station number (such as **2** to **99**) that each program will be received on by subscribers.

The multiple RF signals are then forwarded to a combiner **30** that combines the multiple signals into a single output. That is, the combiner **30** receives the program signals from the channel modulators **25** and combines them onto a single coax cable and forwards the signal to the fiber optic transmitter/receiver **35**. The above-described arrangement and function of channel modulators **25** and combiners **30** may vary with each type of wired media network.

Additional audio, video, or other data signals received from either the antenna farm **15** or from terrestrial sources such as fiber optic or coaxial cables can be routed from the satellite receiver **20** to the service provider ultra-wideband (UWB) device **40**. The service provider UWB device **40** converts the audio, video, or other data signals received from the satellite receiver **20** into a multiplicity of UWB electromagnetic pulses. The service provider ultra-wideband (UWB) device **40** may include several components, including a controller, digital signal processor, an analog coder/decoder, one or more devices for data access management, and associated cabling and electronics. The service provider ultra-wideband (UWB) device **40** may include some, or all of these components, other necessary components, or their equivalents. The controller may include error control, and data compression functions. The analog coder/decoder may include an analog to digital conversion function and vice versa. The data access management device or devices may include various interface functions for interfacing to wired media such as phone lines and coaxial cables.

The digital signal processor in the service provider ultra-wideband (UWB) device **40** modulates the audio, video, or other data signals received from the satellite receiver **20** into a multiplicity of UWB electromagnetic pulses, and may also demodulate UWB pulses received from the subscriber. As defined herein, modulation is the specific technique used to encode the audio, video, or other data into a multiplicity of UWB pulses. For example, the digital signal processor may modulate the received audio, video, or other data signals into a multiplicity of UWB pulses that may have a duration that may range between about 0.1 nanoseconds to about 100 nanoseconds, and may be transmitted at relatively low power, for example, at less than −30 power decibels to −60 power decibels, as measured across the transmitted frequency.

The UWB pulse duration and transmitted power may vary, depending on several factors. Different modulation techniques employ different UWB pulse timing, durations and power levels. The present invention envisions several different techniques and methods to transmit an UWB signal across a wired medium. One embodiment, may for example, use pulse position modulation that varies the timing of the transmission of the UWB pulses. One example of a pulse position modulation system may transmit approximately 10,000 pulses per second. This system may transmit groups of pulses 100 picoseconds early or 100 picoseconds late to signify a specific digital bit, such as a "0" or a "1". In this fashion a large amount of data may be transmitted across a wired medium. Alternatively, the UWB signal may be transmitted in a fashion similar to that described in U.S. Patent Application entitled, "ENCODING AND DECODING ULTRA-WIDEBAND INFORMATION," Ser. No. 09/802,590 (in the name of John H. Santhoff and Rodolfo T. Arrieta), which is referred to and incorporated herein in its entirety by this reference.

An alternative modulation technique may use pulse amplitude modulation to transmit the UWB signal across a wired medium. Pulse amplitude modulation employs pulses of different amplitude to transmit data. Pulses of different amplitude may be assigned different digital representations of "0" or "1." Other envisioned modulation techniques include On-Off Keying that encodes data bits as pulse (1) or no pulse (0), and Binary Phase-Shift Keying (BPSK), or bi-phase modulation. BPSK modulates the phase of the signal (0 degrees or 180 degrees), instead of modulating the position. Spectral Keying, which is neither a PPM nor PAM modulation technique may also be employed. It will be appreciated that other modulation techniques, currently existing or yet to be conceived, may also be employed.

A preferred modulation technique will optimize signal coexistence and pulse reliability by controlling transmission power, pulse envelope shape and Pulse Recurrent Frequencies (PRF). Both pseudo-random and fixed PRFs may be used, with the knowledge that a fixed PRF may create a "carrier-like frequency," which it and its higher order harmonics may interfere with the data carried in conventional RF carrier channels. However, with a pseudo-random PRF the difficulties encountered with a fixed PRF are usually avoided. One embodiment of a pseudo-random PRF modulation technique may include a UWB pulse envelope that is shaped to pre-amplify and compensate for high frequency components that the wired media may naturally attenuate. UWB pulse envelope shaping has the additional advantage of controlling the power spectral density of the transmitted data stream.

Several advantages exist when transmitting UWB pulses through wired media as opposed to transmitting UWB pulses through a wireless medium. Wireless UWB transmissions must consider such issues as Inter-Symbol Interference (ISI) and Multi-User Interference (MUI), both of which can severely limit the bandwidth of UWB transmissions. Some modulation techniques such as Pulse Amplitude Modulation (PAM), which offer the ability for high bit densities are not effective at long wireless distances. These, and other issues, do not apply to UWB pulses transmitted over wired media. In addition, no multipath issues arise and there are no propagation delay problems present in a wired medium. Therefore, it is estimated that an ultra-wideband system may be able to transmit data across a wired medium in a range from 100 Mbit/second to 1 Gbit/second. This data rate will ensure that the bandwidth requirements of any service provider can be met.

A preferred embodiment of the service-provider UWB device **40** will spread the signal energy of the UWB data stream across the a bandwidth that may ranger from 50 MHz to approximately 870 MHz or as discussed above, to 1 GHz, or higher. This will ensure that the signal energy present at any frequency is significantly below the normal noise floor for that frequency band, further ensuring coexistence with conventional RF carrier data.

For example, a UWB pulse would have a duration of about 1 nano-second in a UWB data stream that has a 1 GHz bandwidth. Alternatively, the UWB pulse duration would be tailored to match the available frequency of the specific network. For a CATV or HFCS network located in the United States, an ideal UWB pulse would generally be about 0.5 to 2 nano-seconds in duration. This is because a conventional CATV or HFCS network located in the United States typically utilizes a maximum frequency of approximately 870 MHz, but has the capacity to utilize up to 1 GHz. This bandwidth allows for a 1 to 2 nano-second pulse duration. A narrow pulse width is preferred because more pulses can be transmitted in a discrete amount of time. Pulse widths of up to 2 nano-seconds may be employed to guarantee pulse integrity throughout digitization, transmission, reception and reformation at the UWB subscriber device **50**. Generally, an idealized pulse width would be calculated based on the frequency response of the specific wired media system.

Referring to FIG. **3**, the multiplicity of generated UWB pulses are sent from the service-provider UWB device **40** to the combiner **30**, which combines the UWB pulses with the conventional RF carrier signals. One method to accomplish this task is to couple a wire carrying the conventional RF carrier signals to a standard coaxial splitter. A second wire carrying the UWB pulses is also coupled to the standard coaxial splitter. The combined signals are forwarded to the fiber optic transmitter/receiver **35**. The fiber optic transmitter/receiver **35** converts both the multiplicity of UWB pulses and the conventional RF carrier signals received from the combiner **30** into a corresponding optical signal. The optical signal generator can be either a light-emitting diode, solid state laser diode, or other suitable device. The optical signal is then distributed on fiber optic cables to residential neighborhoods, business districts, universities, colleges or other locations for distribution to subscribers and customers. Other methods and techniques for combining a UWB pulse stream and a conventional RF carrier signal stream may also be employed. For example, the UWB pulse stream my be sent directly to the fiber optic transmitter/receiver **35**, which will then combine the two signals.

Shown in FIG. **3**, a fiber multiplexer node **45** may be located at any one of the locations described above. The optical signals are received by the multiplexer **45** and are

converted back to the combined conventional RF carrier and UWB pulsed signals. The combined signals are forwarded to a subscriber UWB device **50**. The subscriber UWB device **50** can be considered a gateway or router that provides access to the combined signals.

One embodiment of the subscriber UWB device **50** will demodulate the multiplicity of UWB electromagnetic pulses back into a conventional RF carrier signal. The subscriber UWB device **50** may include all, some or additional components found in the service provider UWB device **40**. In this manner, additional bandwidth will be available to the wired media network to provide the additional data and functionality demanded by the customer.

An alternative embodiment of the present invention is illustrated in FIG. **4**. A full service wired UWB communication system **70** is structured to allow for extremely high data rate transmission of video, telephone, internet and audio signals.

The full service UWB system **70** receives audio, video and data information from an antenna farm **15** or from terrestrial sources such as fiber optic or coaxial cables. These signals are forwarded to the satellite receivers **20** as described above with reference to the wired UWB communication system **10**. In addition, signals from a public telephone network **75** are received by a host digital terminal **80**. The host digital terminal **80** modulates multiple voice signals into two-way upstream and downstream RF signals. The voice signals from the host digital terminal **80** are forwarded to the service provider UWB device **40**.

An internet service provider **85** forwards internet data to the internet router **90**. The internet router **90** generates packets, such as TCP/IP packets, which are forwarded to the service provider UWB device **40**.

The service provider UWB device **40** modulates the internet data, the telephony data and the data received from the satellite receivers **20** into a multiplicity of electromagnetic pulses, as described above, and forwards the pulses to the combiner **30**. The combiner combines the UWB pulses with the conventional RF carrier signals and forwards the combined signal to the fiber optic transmitter/receiver **35**. The signals are then converted into an optical signal by either a light emitting diode, solid state laser diode, or other suitable device. The optical signal is then distributed to the fiber multiplexer node **45** located within business districts, residential neighborhoods, universities, colleges and other areas.

The fiber multiplexer node **45** receives the fiber optic signal and converts them back to the combined conventional RF carrier and UWB pulsed signals. The combined signals are forwarded to a subscriber UWB device **50**. The subscriber UWB device **50** can be considered a gateway or router that provides access to the combined signals. The subscriber UWB device **50** demodulates the multiplicity of UWB electromagnetic pulses into RF signals and forwards the RF signals to appropriate locations such as televisions, personal computers or telephones. Alternative embodiment subscriber UWB devices **50** may be located adjacent to televisions sets similar to a set-top box and used to transmit on-demand movies, internet access or pay-per-view programs. Yet another embodiment of the present invention may include a UWB device **50** that may be located within a television set, or computer. The UWB device **50** is constructed to convert and distribute data to computers, network servers, digital or subscription televisions, interactive media devices such as set-top boxes and telephone switching equipment.

The subscriber UWB device **50** may also be configured to transmit UWB pulses wirelessly to provide audio, video, and other data content to personal computers, televisions, PDAs, telephones and other devices. For example, UWB device **50** may include the necessary components to transmit and receive UWB or conventional RF carrier signals to provide access to interfaces such as PCI, PCMCIA, USB, Ethernet, IEEE1394, or other interface standards.

The present invention will also allow for data to be transmitted "upstream" toward the service provider. For example, a conventional CATV or HFCS network reserves frequencies below 50 MHz for upstream traffic. One embodiment of the present invention may include a band-pass filter with stop-bands above 1 GHz, and below 50 MHz to ensure attenuation of UWB pulses so as not to interfere with upstream traffic. These filters also serve the purpose of limiting potential inter-modulation distortion that could be introduced by the UWB pulses.

Alternative embodiments of the present invention may transmits UWB pulses through traditional telephone wires. Depending upon the provider, whether they be a local or long distance carrier, an UWB transmitter/receiver can be located in a regional center, sectional center, primary center, toll center, end-office, or their equivalents.

The present invention of transmitting ultra-wideband signals across a wired medium can employ any type of wired media. For example, the wired media can include optical fiber ribbon, fiber optic cable, single mode fiber optic cable, multi-mode fiber optic cable, plenum wire, PVC wire, and coaxial cable.

In addition, the wired media can include twisted-pair wiring, whether shielded or unshielded. Twisted-pair wire may consist of "pairs" of color-coded wires. Common sizes of twisted-pair wire are 2 pair, 3 pair, 4 pair, 25 pair, 50 pair and 100 pair. Twisted-pair wire is commonly used for telephone and computer networks. It comes in ratings ranging from category **1** to category **7**. Twisted-pair wiring also is available unshielded. That is, the wiring does not have a foil or other type of wrapping around the group of conductors within the jacket. This type of wiring is most commonly used for wiring for voice and data networks. The foregoing list of wired media is meant to be exemplary, and not exclusive.

As described above, the present invention can provide additional bandwidth to enable the transmission of large amounts of data over an existing wired media network, whether the wired media network is a Internet service provider, cable television provider, or a computer network located in a business or university. The additional bandwidth can allow consumers to receive the high speed Internet access, interactive video and other features that they are demanding.

Additional embodiments of the present invention, having added features and functionality will now be described in connection with FIGS. **5**–**13**.

Referring now to FIG. **5**, which illustrates different radio frequency bands occupying a portion of the radio frequency spectrum. As discussed above, North American community access television (CATV) networks provide content using carrier wave communication technology over analog and digital channels starting at channel **2** and running as high as channel **158**, and occupying radio frequency spectrum ranging from about 54 MHz to about 997 MHz (used spectrum **200**). However, different CATV networks may occupy different amounts of radio frequency spectrum, with older systems using frequencies ranging from about 54 MHz to about 450 MHz. As shown in FIGS. **3** and **4**, and discussed

above, a coaxial cable is routed from the fiber multiplexer node **45** to the home, apartment complex, hospital, etc. Once inside the home, business, hospital, apartment complex or other group of buildings, the coaxial cable is used to deliver the content to televisions, personal computers, monitors, or other devices. This coaxial cable is generally capable of transmitting radio frequency signals having frequencies up to about 10 GHz. Therefore, as shown in FIG. **5**, un-used spectrum **210**, ranging from about 1 GHz to about 3 GHz, is vacant. In addition, the lightly-used spectrum **220** between about 5 MHz to about 54 MHz is generally sparsely occupied by frequency channels dedicated to "upstream" communications (i.e., between the customer and the CATV provider).

The present invention provides methods and apparatus to transmit ultra-wideband (UWB) pulses that occupy radio frequencies that are not used by other electromagnetic signals present in a wire medium of interest. In the CATV example described above, UWB pulses may be transmitted in the un-used spectrum **210** or in the lightly-used spectrum **220**.

It will be appreciated that the specific radio frequencies employed by the present invention will vary, depending upon the type of network. Generally, different networks use different radio frequencies, thus leaving different frequencies vacant, or un-used. The present invention may use any un-used, or lightly-used radio frequencies in a network. As shown in FIGS. **3** and **4**, and discussed above, in a CATV network, coaxial cable is routed from the fiber multiplexer node **45** to a subscriber UWB device **50** that may located in the home, apartment complex, hospital, etc. Once inside the home, business, hospital, apartment complex or other group of buildings, the coaxial cable is used to deliver video, voice, data, Internet content, or other content to televisions, personal computers, monitors, or other devices. The present invention of using un-used frequencies or lightly-used frequencies to transmit and receive ultra-wideband signals may be employed at either the fiber multiplexer node **45** or the subscriber UWB device **50**. In a preferred embodiment the subscriber UWB device **50** creates, transmits, and receives ultra-wideband pulses that use radio frequency(s) that are not used by other signals present on wire media within any wire network of interest.

By employing un-used radio frequencies to carry additional content, such as video, voice, data, Internet content, or other types of content, the present invention can increase the bandwidth of a network.

Referring now to FIG. **6**, one method of transmitting ultra-wideband pulses in a CATV network is illustrated. Binary digits, or bits **310** are modulated into ultra-wideband (UWB) pulses occupying the unused spectrum **210** and injected into the wire medium (in this case a coaxial cable) that is carrying CATV content. In this embodiment, the bits **310** are modulated by UWB modulator **315** into UWB pulses **320** occupying the bandwidth of 0 Hz to about 1 GHz, with harmonic copies residing in higher frequency ranges, as shown in FIG. **6**A. As discussed above, a number of different modulation methods may be employed by the present invention. One modulation method may be "coded recurrence" modulation, that is described in co-pending Unites States patent applications: Ser. No. 10/294,021, filed Nov. 12, 2002; Ser. No. 10/747,606, filed Dec. 29, 2003; and Ser. No. 10/747,608, filed Dec. 29, 2003, all entitled "Ultra-wideband Pulse Modulation System and Method," and all of which are referred to and incorporated herein in their entirety by this reference.

As shown in FIG. **6**, the UWB pulses **320** are passed through a low-pass filter **330** that passes radio frequencies below 1 gigahertz (GHz), thereby removing the harmonic copies, as shown in FIG. **6**B. The filtered UWB pulses **340** are mixed by mixer **350** with a sinusoid of frequency ω_c=1 GHz. This produces upward-shifted UWB pulses **360**, that occupy the radio frequencies between 1 GHz to 2 GHz, as shown in FIG. **6**C. The upward-shifted UWB pulses **360** are then injected into the wire medium of interest, such as CATV network, causing no interference with the CATV channel content that occupies used spectrum **200**. It will be appreciated that the radio frequency spectrum occupied by the upward-shifted UWB pulses **360** may be greater than or less than the 1 GHz discussed above. For example, the upward-shifted UWB pulses **360** may occupy any desired portion of the radio frequency spectrum ranging from 1 GHz to 10 GHz. In addition, because the upward-shifted UWB pulses **360** are transmitted at radio frequencies that are not used by the network, the power used to transmit the upward-shifted UWB pulses **360** may be greater than the power used to transmit UWB pulses that share the same radio frequencies used by other signals in the network.

Alternatively, the UWB pulses may be generated directly at the desired frequency. By using an arbitrary waveform generator with a sufficiently high frequency capability, UWB pulses can be generated to have any frequency content up to the Nyquist frequency of the waveform generator. This embodiment eliminates the need for the filter **330** and mixer **350** illustrated in FIG. **6**.

Referring now to FIG. **7**, another method of transmitting ultra-wideband pulses in a CATV network is illustrated. Bits **310** are modulated by UWB modulator **315** into UWB pulses **320** occupying radio frequency spectrum from about 0 Hz to about 1 GHz, with harmonic copies residing in higher frequency ranges, as shown in FIG. **7**A. The UWB pulses **320** are passed through a bandpass filter (BPF) **380** structured to pass frequencies above 1 GHz and below 2 GHz, thereby removing the "baseband" UWB waveform and its harmonic copies above 2 GHz, as shown in FIG. **7**B. The upward shifted UWB pulses **360** now occupy the frequency spectrum between about 1 and about 2 GHz, which comprises a portion of the unused spectrum **210**. As discussed above, the upward-shifted UWB pulses **360** may occupy any desired portion of the radio frequency spectrum ranging from 1 GHz to 10 GHz. The upward shifted UWB pulses **360** are then injected into the wire medium, causing no interference with the CATV channel content that occupies used spectrum **200**.

Referring now to FIG. **8**, a method for recovering the bits **310** is illustrated. The total signal **370** that includes both CATV channel content in used spectrum **200** and the upward shifted UWB pulses **360** in unused spectrum **210** is obtained from the wire medium, as shown in FIG. **8**A. It is passed through a band-pass filter (BPF) **380** structured to pass frequencies between about 1 GHz and 2 GHz, thus eliminating the CATV channel content in used spectrum **200** and isolating the upward shifted UWB pulses **360** in unused spectrum **210**, as shown in FIG. **8**B. It will be appreciated that BPF **380** may be structured to pass other frequencies of interest, such as any group of frequencies between 1 GHz to 10 GHz.

The upward shifted UWB pulses **360** are then mixed by mixer **350** with a sinusoid of frequency ω_c=1 GHz producing UWB copies **345** in the frequency ranges of about 0 to 1 GHz and about 2 to 3 GHz, as shown in FIG. **8**C. Passing the UWB copies **345** through a low-pass filter (LPF) **330** produces the filtered UWB pulses **340**, as shown in FIG. **8**D,

which are demodulated by UWB demodulator **390** to recover the original bits **310**. Bits **310** comprising video, images, audio, data and text may be transmitted as shown in this embodiment substantially simultaneously and without interfering with content present in the used spectrum **200**.

Referring to FIGS. **9**A and **9**B, another embodiment of the present invention utilizes the lightly used spectrum **220** that is generally used for "upstream" communications. This spectrum spans about 5 MHz to about 54 MHz, and may include a TV-IF band **400**. The TV-IF band usually occupies about 6 MHz of radio frequency spectrum. "IF" stands for "intermediate frequency", a middle range frequency to which received signals are down-converted in the electronic circuitry of a television ("TV"), and in which the majority of signal amplification, processing, and filtering steps occur. In addition, there may be one or more upstream channels, or bands **410** used for upstream communications. Within this embodiment, as shown in FIG. **9**C, bits **310** are modulated into ultra-wideband (UWB) pulses occupying substantially the entire lightly used spectrum **220** between about 5 MHz and about 54 MHz. The UWB pulses are passed through a bandpass filter structured to pass unused frequencies **420** so that the UWB pulses do not interfere with any upstream channels **410** or the TV-IF band **400**. That is, UWB pulses may occupy portions of the lightly used spectrum **220** that are not used by the CATV network.

Referring now to FIGS. **9**B and **10**, another embodiment of the present invention is illustrated that utilizes substantially all of the CATV bandwidth, which comprises used spectrum **200** and lightly used spectrum **220**. In this embodiment, ultra-wideband pulses are transmitted using not-in-use frequencies **450**, that avoid in-use frequencies **405**. FIG. **10** illustrates a portion of a network, such as a CATV network, employing televisions **60** and/or computers **95** that may use different frequencies at different times. Both TVs, or TV monitors **60** and computers **95** may include ultra-wideband transceivers, or may have "set-top-boxes" or other devices that include ultra-wideband transceivers. For example, in a CATV network, the TV's **60** may display one, or two TV channels. A computer **95** may also display one, or two TV channels. According to this embodiment of the present invention, downstream CATV signals **500** are routed into a dynamic filter **505** that is configured to dynamically pass frequency content corresponding to displayed TV channels. The displayed channels are identified by channel detector **510** that determines which TV channels are being displayed by devices **60** and **95**, and forwards this displayed TV channel information **512** to the dynamic filter **505**.

The dynamic filter **505** filters the CATV signal, producing a filtered CATV signal **515** that comprises the specific channels requested by devices **60** and **95**. In this embodiment, devices **60** and **95** may have the capability to communicate with each other, the dynamic filter **505** and the channel detector **510** using UWB pulses. The devices **60** and **95** receive command information **540** containing in-use, or displayed channel identities from the channel detector **510**. The command information **540** may be transmitted, for example, using UWB pulses over the cable network or wirelessly.

As shown in FIG. **10**, one embodiment of a channel detector **510** comprises a passive electromagnetic sensor **511** and a wireless UWB transmitter (not shown). Sensor **511** captures the electromagnetic field emissions containing the content of any displayed channel **512** and transmits this information wirelessly to the channel detector **510**. The channel detector **510** also receives the CATV signal **500** and performs a correlation between the captured emissions received from the sensor **511** and the various channels contained in the CATV signal. From the correlation, the displayed channel(s) **512** are determined, and this information is transmitted to the dynamic filter **505**.

For example, when a user selects a new CATV channel for display on device **60** or **95**, the channel detector **510** detects the instantaneous absence of the previously displayed channel on the device **60** or **95**, and immediately transmits this new display information **512** to the dynamic filter **505** directing the dynamic filter **505** to pass the new requested channel to device **60** or **95**. At substantially the same time, the ultra-wideband pulses are transmitted using the new not-in-use frequencies **450**, that avoid the new in-use frequencies **405** that correspond to the newly displayed CATV channel.

Bits **310**, carried by ultra-wideband pulses may then be passed to the devices **60** and **95** using radio frequencies, or channels that are not being displayed by devices **60** and **95**. The additional bits **310** may carry other information, such as security video information that may be displayed within a discrete "pop-up" window on device **60** and **95**. Or bits **310** may be used to transmit Internet data, HDTV-formatted video, or other data.

Referring now to FIG. **11**, one embodiment of the dynamic filter **505** is illustrated. The CATV signal **500** is received by an analog-to-digital converter (ADC) **600**. The resulting digital signal is passed to a digital signal processor (DSP) **610** that functions as a dynamic bandpass filter to reject all frequency content other than the frequency bands corresponding to CATV channels displayed by devices **60** and **95**. The channel detector **510** passes to the DSP **610** the display channel **512** information which the DSP **610** uses to determine the frequencies, or channels for filtering. The filtered digital signal generated by the DSP **610** is passed to a digital-to-analog converter (DAC) **620** that generates the filtered CATV signal **515**.

Referring to FIG. **12**, another embodiment of the dynamic filter **505** is illustrated. This embodiment is based on using multiple filters **690**. Preferably, each filter **690** is a bandpass filter. In this embodiment, the CATV signal **500** enters a bank of filters **690** arranged in a parallel architecture. The number of filters **690** may depend on several factors, including but not limited to expense, performance, or capacity requirements of the deployed invention. Each filter **690** is dynamically configured by a filter controller **630** to pass frequency content corresponding to a single CATV channel displayed by a device **60** or **95**. The filter controller **630** receives displayed channel **512** information from the channel detector **510** and uses it to configure each filter **690** in the bank, one filter **690** for each displayed channel on the cable network. If there are fewer channels being displayed by devices **60** or **95** on the network than the number of filters **690**, then each of the filters **690** not required for channel filtering is configured to block all remaining channels in the CATV signal **500**. The output from each filter **690** comprises either the signal content for a single channel or a null signal comprising no energy. The output from all of the filters **690** is summed by summer **695**, resulting in filtered signal **515** comprising the in-use, or displayed channel content with substantially all other content eliminated. Since each in-use channel on the cable system requires a bandpass filter, the number of bandpass filters may be determined, for example, by anticipating the number of connected devices **60** and/or **95** requiring channel content.

FIG. **13** illustrates another embodiment of the dynamic filter **505**. The CATV signal **500** enters a parallel bank of processing streams, wherein each processing stream com-

prises the steps of: 1) mixing the CATV signal **500**, with mixers **350** with a sinusoid equal to the center frequency of one of the in-use, or displayed CATV channels, produced by controllable sinusoid generators **347**; 2) routing the resulting frequency-shifted signals into gated lowpass filters **660** structured to reject all frequency content greater than the bandwidth of the displayed cable channel; 3) mixing the resulting, filtered baseband signal (using mixers **350**) with a sinusoid identical to the sinusoid of step (1); and 4) summing (using summer **695**) the output from each mixer **350** to generate a composite signal **515** containing substantially only the channels in use, or displayed on the network, with substantially all other frequency content eliminated.

Displayed channel **512** information identifying the CATV channels in use by the devices **60** and/or **95** is routed from the channel detector **510** to the filter controller **635**. The filter controller **635** routes a control signal uniquely associated with one in-use, or displayed CATV channel to each of the controllable sinusoid generators **347**. Each sinusoid generators **347** uses the control signal to generate a sinusoid waveform with frequency equal to the center frequency of one of the in-use, or displayed CATV channels. If there are fewer in-use channels than processing streams, then the gated lowpass filter for each processing stream that is not required for channel processing is set open via a control signal transmitted by the filter controller **635**. Since each in-use, or displayed channel on the network requires a single processing stream, the number of processing streams may be determined, for example, by anticipating the number of connected devices **60** and/or **95** requiring channel content.

Another feature of the present invention comprises a synchronization signal, or tone that is broadcast by the subscriber UWB device **50**, shown in FIGS. **3** and **4**. In one embodiment of this feature of the present invention, a substantially continuous carrier wave, sinusoidal wave, or square wave is broadcast by the subscriber UWB device **50** into any one of: the used spectrum **200**, the unused spectrum **210** or the lightly used spectrum **220** shown in FIG. **5**. For example, the synchronization signal, or tone that is broadcast by the subscriber UWB device **50** may be transmitted at 750 MHz, 1 GHz, 2 GHz or any other frequency. For example, in one embodiment, the synchronization signal is transmitted at the "guard" frequencies of a CATV network. The "guard" frequencies or band, are bands of frequencies at the upper and lower limits of an CATV channel. In another embodiment, the synchronization signal, or tone is broadcast at an integer multiple of a system clock that is included within the ultra-wideband devices described herein. Preferably the synchronization signal, or tone is broadcast into the CATV, or other type of network using a frequency that does not interfere with CATV content, or other content present in another type of network. However, a specific frequency that previously provided content may be re-assigned to carry the synchronization signal.

The synchronization signal, or tone that is broadcast by the subscriber UWB device **50** enables any ultra-wideband (UWB) devices, or any device that is UWB-enabled (such as TVs **60** or computers **95**) to obtain UWB pulse timing synchronization information.

Receiving devices connected to the network may monitor the synchronization signal to synchronize the device's sampling clock with the transmitter's clock. Since the synchronization signal uses a frequency outside of the range of frequencies used by the CATV channels, it causes substantially no interference with the CATV channels and, further, substantially no interference with any UWB pulses present in the network.

Having a synchronization signal provides many benefits. Efficient clock synchronization allows relatively large data payloads per frame while simultaneously allowing more frequent clock adjustments that correct any clock drift. In digital computers or controllers, clocks pace the operation of the device, and thus the communication system. Thus, the UWB-enabled TVs **60** and computers **95** contain clocks that may lose synchronization relative to each other. A synchronization signal that corrects for clock drift improves the efficiency of the communication system.

For example, bits **310** are transmitted in "frames" that comprise groups of UWB pulses. Currently, the beginning portion of each "frame," called a "preamble" contains synchronization patterns, or information. On receiving the preamble, a receiver uses the synchronization pattern to compute any necessary clock adjustment. The clock is not adjusted until the next frame is received, at which time the process is repeated and the receiver's sampling clock is readjusted. A longer period between synchronizations generally equates to more clock drift. Also, the period between synchronizations is generally a function of the amount of data in the "payload" portion of the frame. A large payload per frame increases data rates because of lower computational requirements due to fewer synchronizations, but a increase in data rates come with the risk of synchronization loss, which may cause data corruption, and possibly lower quality-of-service. Conversely, smaller data payloads improve quality-of-service because clock synchronizations are more frequent, enabling clock drift correction before synchronization is lost. Quality-of-service comes at the price, however, of more computational overhead and related latencies, and data rate suffers because of the smaller payloads. By providing a synchronization signal, the present invention allows greater data payloads per frame while simultaneously providing frequent checks, and adjustments for clock drift.

For example, under a pulse-position modulation (PPM) communication scheme, where UWB pulses are placed in specific locations within a "frame," which does not use a synchronization signal as described herein, 400 picosecond UWB pulses are transmitted with a 100 MHz pulse transmission rate, which equates to periods of 10 nanoseconds between pulses, resulting in a 4% duty cycle per pulse (i.e., 400 ps/10 ns). A synchronization signal with a frequency of 1 GHz broadcast into the network oscillates at a rate 10 times the pulse transmission rate. Using a phase locked loop, a device well known in the art for tracking the frequency of a sinusoidal waveform, the receiver component of a UWB device may therefore acquire clock synchronization information from the synchronization signal at 10 times the rate at which it is sampling individual UWB pulses on a 4% duty cycle. The receiver in a UWB-enabled device, like TVs **60** and computers **95** may therefore maintain their clock frequency precisely, eliminating the need to synchronize between frame deliveries. The requirement for discrete frames of data that have synchronization patterns contained in their preambles is significantly reduced, therefore allowing UWB devices to transmit data frames of arbitrary length, considerably improving data throughput. That is, by providing a synchronization signal according to one embodiment of the present invention, relatively large data payloads per frame may be transmitted while simultaneously enabling more frequent clock checks and adjustments that compensate for clock drift.

Thus, it is seen that an apparatus and method for transmitting and receiving ultra-wideband pulses through a wire medium is provided. One skilled in the art will appreciate

that the present invention can be practiced by other than the above-described embodiments, which are presented in this description for purposes of illustration and not of limitation. The description and examples set forth in this specification and associated drawings only set forth preferred embodiment(s) of the present invention. The specification and drawings are not intended to limit the exclusionary scope of this patent document. Many designs other than the above-described embodiments will fall within the literal and/or legal scope of the following claims, and the present invention is limited only by the claims that follow. It is noted that various equivalents for the particular embodiments discussed in this description may practice the invention as well.

What is claimed is:

1. A communication method for a wire medium, the method comprising the steps of:
   - transmitting a carrier wave signal that occupies a first portion of a radio frequency spectrum; and
   - transmitting a plurality of ultra-wideband pulses that occupy a second portion of the radio frequency spectrum.

2. The communication method of claim 1, wherein the first portion of the radio frequency spectrum and the second portion of the radio frequency spectrum comprise different radio frequencies.

3. The communication method of claim 1, wherein the carrier wave signal comprises a substantially continuous sinusoidal wave.

4. The communication method of claim 1, wherein the first portion of the radio frequency spectrum ranges from about 5 megahertz to about 500 megahertz.

5. The communication method of claim 1, wherein the second portion of the radio frequency spectrum ranges from about 500 megahertz to about 10 gigahertz.

6. The communication method of claim 1, wherein each of the plurality of ultra-wideband pulses comprises a pulse of electromagnetic energy having a duration that can range between about 0.1 nanoseconds to about 1 microsecond.

7. The communication method of claim 1, further comprising the step of:
   - transmitting a synchronization signal within either the first or the second portions of the radio frequency spectrum.

8. The communication method of claim 7, wherein the synchronization signal comprises a substantially continuous sinusoidal wave.

9. The communication method of claim 7, wherein the synchronization signal provides a common timing source.

10. The communication method of claim 1, wherein the wire medium is selected from a group consisting of: an optical fiber ribbon, a fiber optic cable, a single mode fiber optic cable, a multi-mode fiber optic cable, a twisted pair wire, an unshielded twisted pair wire, a plenum wire, a PVC wire, and a coaxial cable.

11. A communication system for a wire medium, comprising:
   - a transmitter structured to transmit a carrier wave signal that occupies a first portion of a radio frequency spectrum; and
   - an ultra-wideband transmitter structured to transmit a plurality of ultra-wideband pulses that occupy a second portion of the radio frequency spectrum.

12. The communication system of claim 11, wherein the first portion of the radio frequency spectrum and the second portion of the radio frequency spectrum comprise different radio frequencies.

13. The communication system of claim 11, wherein the carrier wave signal comprises a substantially continuous sinusoidal wave.

14. The communication system of claim 11, wherein the first portion of the radio frequency spectrum ranges from about 5 megahertz to about 500 megahertz.

15. The communication system of claim 11, wherein the second portion of the radio frequency spectrum ranges from about 500 megahertz to about 10 gigahertz.

16. The communication system of claim 11, wherein each of the plurality of ultra-wideband pulses comprises a pulse of electromagnetic energy having a duration that can range between about 0.1 nanoseconds to about 1 microsecond.

17. The communication system of claim 11, further comprising a synchronization signal located within either the first or the second portions of the radio frequency spectrum.

18. The communication system of claim 17, wherein the synchronization signal comprises a substantially continuous sinusoidal wave.

19. The communication system of claim 17, wherein the synchronization signal provides a common timing source.

20. The communication system of claim 11, wherein the wire medium is selected from a group consisting of: an optical fiber ribbon, a fiber optic cable, a single mode fiber optic cable, a multi-mode fiber optic cable, a twisted pair wire, an unshielded twisted pair wire, a plenum wire, a PVC wire, and a coaxial cable.

21. A method of transmitting data through a wire network, the method comprising the steps of:
   - transmitting a plurality of carrier wave signals that occupy a first portion of a radio frequency spectrum; and
   - transmitting a plurality of ultra-wideband pulses that occupy a second portion of the radio frequency spectrum.

22. The method of claim 21, wherein the first portion of the radio frequency spectrum ranges from about 5 megahertz to about 500 megahertz.

23. The method of claim 21, wherein the second portion of the radio frequency spectrum ranges from about 500 megahertz to about 10 gigahertz.

24. The method of claim 21, wherein each of the plurality of carrier wave signals comprises a substantially continuous sinusoidal wave.

25. The method of claim 21, wherein each of the plurality of ultra-wideband pulses comprises a pulse of electromagnetic energy having a duration that can range between about 0.1 nanoseconds to about 1 microsecond.

26. The method of claim 21, further comprising the step of:
   - transmitting a synchronization signal within either the first or the second portions of the radio frequency spectrum.

27. The method of claim 26, wherein the synchronization signal comprises a substantially continuous sinusoidal wave.

28. The method of claim 26, wherein the synchronization signal provides a common timing source.

29. The method of claim 21, wherein the wire medium is selected from a group consisting of: an optical fiber ribbon, a fiber optic cable, a single mode fiber optic cable, a multi-mode fiber optic cable, a twisted pair wire, an unshielded twisted pair wire, a plenum wire, a PVC wire, and a coaxial cable.

30. The method of claim 21, wherein the wire network is selected from a group consisting of: a power line, an optical network, a cable television network, a community antenna television network, a community access television network, a hybrid fiber coax system network, a public switched

telephone network, a wide area network, a local area network, a metropolitan area network, a TCP/IP network, a dial-up network, a switched network, a dedicated network, a nonswitched network, a public network and a private network.

31. A method of transmitting a plurality of ultra-wideband pulses, the method comprising the steps of:

providing a wire network that uses a group of discrete radio frequencies;

determining which of the discrete radio frequencies are occupied by a carrier wave;

transmitting a plurality of ultra-wideband pulses that occupy the discrete radio frequencies that are not occupied by a carrier wave.

32. The method of claim 31, wherein the step of determining which of the discrete radio frequencies are occupied by a carrier wave comprises sampling each of the discrete radio frequencies to determine if a carrier wave is present.

33. The method of claim 31, further comprising the step of:

transmitting a synchronization signal that occupies at least one discrete radio frequency.

34. The method of claim 33, wherein the synchronization signal comprises a substantially continuous sinusoidal wave.

35. The method of claim 33, wherein the synchronization signal provides a common timing source.

36. The method of claim 31, wherein each of the plurality of ultra-wideband pulses comprises a pulse of electromagnetic energy having a duration that can range between about 0.1 nanoseconds to about 1 microsecond.

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DISTRICT COURT
SOUTHERN DISTRICT OF CALIFORNIA
SAN DIEGO DIVISION

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Amount.: $350.00 CK
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Total-> $350.00

FROM: PULSE LINK V. TZERO TECH.
CIVIL FILING
3 COPIES

JS 44 (Rev. 11/04)

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON THE REVERSE OF THE FORM.)

I. (a) PLAINTIFFS
PULSE~LINK INCORPORATED

DEFENDANTS
TZERO TECHNOLOGIES INCORPORATED

'07 CV 2156 BTM (WMC)

FILED

07 NOV -9 AM 11: 12

CLERK US DISTRICT COURT
SOUTHERN DISTRICT OF CALIFORNIA

BY: DEPUTY

(b) County of Residence of First Listed Plaintiff San Diego
(EXCEPT IN U.S. PLAINTIFF CASES)

County of Residence of First Listed Santa Clara
(IN U.S. PLAINTIFF CASES ONLY)
NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE LAND INVOLVED.

(c) Attorney's (Firm Name, Address, and Telephone Number)
John M. Benassi (SBN 74137); Matthew C. Lapple (SBN 193546)
Samuel R. Hellfeld (SBN 234421)
Heller Ehrman LLP
4350 La Jolla Village Drive, 7th Floor
San Diego, CA 92122-1246

Attorneys (If Known)

II. BASIS OF JURISDICTION (Place an "X" in One Box Only)

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question (U.S. Government Not a Party)
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place an "X" in One Box for Plaintiff and One Box for Defendant) (For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated *or* Principal Place of Business In This State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated *and* Principal Place of Business In Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. NATURE OF SUIT (Place an "X" in One Box Only)

CONTRACT
☐ 110 Insurance
☐ 120 Marine
☐ 130 Miller Act
☐ 140 Negotiable Instrument
☐ 150 Recovery of Overpayment & Enforcement of Judgment
☐ 151 Medicare Act
☐ 152 Recovery of Defaulted Student Loans (Excl. Veterans)
☐ 153 Recovery of Overpayment of Veteran's Benefits
☐ 160 Stockholders' Suits
☐ 190 Other Contract
☐ 195 Contract Product Liability
☐ 196 Franchise

REAL PROPERTY
☐ 210 Land Condemnation
☐ 220 Foreclosure
☐ 230 Rent Lease & Ejectment
☐ 240 Torts to Land
☐ 245 Tort Product Liability
☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
☐ 310 Airplane
☐ 315 Airplane Product Liability
☐ 320 Assault, Libel & Slander
☐ 330 Federal Employers' Liability
☐ 340 Marine
☐ 345 Marine Product Liability
☐ 350 Motor Vehicle
☐ 355 Motor Vehicle Product Liability
☐ 360 Other Personal Injury

PERSONAL INJURY
☐ 362 Personal Injury—Med. Malpractice
☐ 365 Personal Injury — Product Liability
☐ 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
☐ 370 Other Fraud
☐ 371 Truth in Lending
☐ 380 Other Personal Property Damage
☐ 385 Property Damage Product Liability

CIVIL RIGHTS
☐ 441 Voting
☐ 442 Employment
☐ 443 Housing/ Accommodations
☐ 444 Welfare
☐ 445 Amer. w/Disabilities - Employment
☐ 446 Amer. w/Disabilities - Other
☐ 440 Other Civil Rights

PRISONER PETITIONS
☐ 510 Motions to Vacate Sentence
Habeas Corpus:
☐ 530 General
☐ 535 Death Penalty
☐ 540 Mandamus & Other
☐ 550 Civil Rights
☐ 555 Prison Condition

FORFEITURE/PENALTY
☐ 610 Agriculture
☐ 620 Other Food & Drug
☐ 625 Drug Related Seizure of Property 21 USC 881
☐ 630 Liquor Laws
☐ 640 R.R. & Truck
☐ 650 Airline Regs.
☐ 660 Occupational Safety/Health
☐ 690 Other

LABOR
☐ 710 Fair Labor Standards Act
☐ 720 Labor/Mgmt. Relations
☐ 730 Labor/Mgmt.Reporting & Disclosure Act
☐ 740 Railway Labor Act
☐ 790 Other Labor Litigation
☐ 791 Empl. Ret. Inc. Security Act

BANKRUPTCY
☐ 422 Appeal 28 USC 158
☐ 423 Withdrawal 28 USC 157

PROPERTY RIGHTS
☐ 820 Copyrights
☒ 830 Patent
☐ 840 Trademark

SOCIAL SECURITY
☐ 861 HIA (1395ff)
☐ 862 Black Lung (923)
☐ 863 DIWC/DIWW (405(g))
☐ 864 SSID Title XVI
☐ 865 RSI (405(g))

FEDERAL TAX SUITS
☐ 870 Taxes (U.S. Plaintiff or Defendant)
☐ 871 IRS—Third Party 26 USC 7609

OTHER STATUTES
☐ 400 State Reapportionment
☐ 410 Antitrust
☐ 430 Banks and Banking
☐ 450 Commerce
☐ 460 Deportation
☐ 470 Racketeer Influenced and Corrupt Organizations
☐ 480 Consumer Credit
☐ 490 Cable/Sat TV
☐ 810 Selective Service
☐ 850 Securities/Commodities/ Exchange
☐ 875 Customer Challenge 12 USC 3410
☐ 890 Other Statutory Actions
☐ 891 Agricultural Acts
☐ 892 Economic Stabilization Act
☐ 893 Environmental Matters
☐ 894 Energy Allocation Act
☐ 895 Freedom of Information Act
☐ 900 Appeal of Fee Determination Under Equal Access to Justice
☐ 950 Constitutionality of State Statutes

V. ORIGIN (Place an "X" in One Box Only)

☒ 1 Original Proceeding ☐ 2 Removed from State Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from another district (specify) ☐ 6 Multidistrict Litigation ☐ 7 Appeal to District Judge from Magistrate Judgment

VI. CAUSE OF ACTION

Cite the U.S. Civil Statute under which you are filing **(Do not cite jurisdictional statutes unless diversity):**
35 U.S.C. Sections 271, et seq.

Brief description of cause:
Plaintiff, Pulse~Link's, patents 6,895,034 and 7,099,368 have been infringed upon by defendant, Tzero Technologies

VII. REQUESTED IN COMPLAINT: ☐ CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23 **DEMAND $**

CHECK YES only if demanded in complaint:
JURY DEMAND: ☒ Yes ☐ No

VIII. RELATED CASE(S) IF ANY (See instructions): JUDGE LORENZ DOCKET NUMBER 07 CV 1125 L (AJB)

DATE
November 9, 2007

SIGNATURE OF ATTORNEY OF RECORD
John Benassi (SRH)

FOR OFFICE USE ONLY

RECEIPT # 144367 AMOUNT $350 11/9/07 BH APPLYING IFP JUDGE MAG. JUDGE

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